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Guidebook to Places of Geologic Interest

IN THE

Lehigh Valley

PENNSYLVANIA

By

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GUIDEBOOK TO PLACES OF GEOLOGIC INTEREST IN THE LEHIGH VALLEY, PENNSYLVANIA

By Benjamin L. Miller

Purpose of Bulletin

In recent years there has been an increasing interest in outdoor science of all kinds—botany, forestry, zoology, geology, mineralogy, etc.—an interest which almost every educator feels should be encouraged. The Boy Scout movement is entitled to a large share of the credit for this desirable trend, although the Appalachian Mountain clubs and various other hiking clubs also have promoted desirable outdoor activities. Both the professional and the amateur scientists have contributed much time and effort to the rationalization of programs for the education of the public in the different natural sciences in their particular localities. Nevertheless, curious, erroneous explanations of the natural phenomena are still extant. This is particularly true in the field of geology. For example, not infrequently is one told that the Lehigh Valley as it is today was mainly formed by the erosion accomplished by glacial ice; that the "Ringing Rocks," the residual boulder fields of Haycock Mountain, and the "Devil's Potato Patch" of Little Gap, and "Big Rock" (Bowers' Rock) are of glacial origin; and that the Delaware Water Gap and Lehigh Gap were formed by impounded water on the north side of the mountain bursting the barrier and releasing the dammed waters.

Therefore a guide to those places in the Lehigh Valley that may be of interest to the general public seems advisable. This bulletin is intended primarily for the layman interested in geology, and so far as possible is written without the use of technical terms.

The writer also has in mind fellow geologists who occasionally visit the region. The Lehigh Valley is easily accessible to students from a considerable number of educational institutions and from time to time parties of geological students are conducted to portions of the region.

For those persons who desire more detailed information, the forthcoming volumes of this Survey on the geography and geology of Lehigh and Northampton counties are recommended.

This guidebook is one of a series which is being prepared by the Pennsylvania Topographic and Geologic Survey. The books are based partly upon the annual field trips of the Field Conference of Pennsylvania Geologists and partly upon the Educational Field Trips in Geology sponsored by the Survey. The idea of preparing the present bulletin was inspired by the Field Conference trip held several years ago in the Lehigh Valley. That part of the earlier excursion which dealt with the Delaware and Lehigh Gap sections has been published in the Survey's Bulletin G 12. It is therefore omitted from

this discussion. On the other hand, the original trips in and about the Lehigh Valley have been amplified and new itineraries introduced. By this means, one obtains not only a broad picture of the Lehigh Valley geology itself, but also of the bordering regions, particularly the crystalline hills along its southern border and the Triassic lowland still farther south.

Other guidebooks in the series are:

G 8. A Paleozoic Section in South-Central Pennsylvania.
G 11. A Paleozoic Section at Delaware Water Gap.
G 12. Highway Geology, Philadelphia to Pittsburgh.
G 13. Highway Geology, Dauphin to Sunbury.
G 14. Highway Geology, Pottsville to Leesport.
G 15. Guidebook to the Geology about Reading, Pa.
G 17. Guidebook to the Geology about Pittsburgh.

Introduction

In most places a named valley is coextensive with the drainage basin of a stream bearing the same name. This is not the case of the Lehigh Valley in that the upper portions of the drainage basin of the Lehigh River are generally not included in the popular usage of the term, and some localities not within the basin but connected with the life and business of the lower part of the Lehigh River valley are included. In this discussion the prevailing usage rather than the exact geographic designation will be followed. Those portions of the anthracite region and the Pocono Plateau drained by the headwaters of the Lehigh River are omitted and some localities drained directly by minor tributaries of the Delaware River are described. All these are easily accessible to the inhabitants of the Lehigh Valley.

The Lehigh Valley has long been one of the most important industrial sections of Pennsylvania. From almost the first settlement, agriculture, mining, quarrying and manufacturing have developed side by side. Naturally at first agriculture was the main consideration but at present it is of lesser importance than manufacturing and the industries associated with quarrying.

The Lehigh Valley is strategically located in that it is closer to the metropolitan areas of New York City and Philadelphia than any other locality with as varied interests. It contains a greater population than any other area of equal size within the State outside the Philadelphia, Pittsburgh and Scranton-Wilkes-Barre regions.

The name "Lehigh" seems somewhat prophetic when we recall its origin. The Indians going northward from what is now Bucks County followed a single trail to the place where they crossed the Lehigh River in the east part of the present city of Bethlehem. On the left bank the trail divided, one branch going northeast to the Wind Gap, another northwest to the Lehigh Gap, and another west along the river. For this reason they gave the name "Lechauweki" to the river, a word mean "where there are forks." The corruption of this term gives us the present name of Lehigh.

The aptness of the name is apparent. From this region, trails now lead to every part of the world, no matter how remote. Products from this Valley are found everywhere on the face of the earth. Some trails connect us with most remote places to bring in raw products necessary in the manufacture of scores of specialized products but more trails are utilized for distribution.

Nature's Part in the Development of the Lehigh Valley

For a billion years the Lehigh Valley has been in process of development. The oldest rocks whose age can be determined with certainty occur in the vicinity of Easton where a rare radium-bearing mineral, thorianite, has shown an age of 850,000,000 years since the solidification and crystallization of a mass of igneous rock intruded into much older rocks.

During the past billion years, the area now embraced in the Lehigh Valley has witnessed tremendous changes, some of which have left records that can be deciphered, whereas the records of events of other periods have been largely destroyed.

PHYSIOGRAPHY

Several different classifications have been proposed for the physiographic features represented in the area under discussion. The most recent and perhaps the most comprehensive one is that of N. M. Fenneman.[1] According to his scheme, portions of three different provinces are represented in the Lehigh Valley. In order from north to south they are: (1) the Ridge and Valley Province, (2) the Reading Prong of the New England Province and (3) the Triassic Lowland of the Piedmont Province. These are practically coextensive with single or groups of geological formations, as will be described under each division.

Ridge and Valley Province. The greater portion of the region lies within the Ridge and Valley Province. It starts at the northern base of South Mountain, where the Cambrian sandstone (Hardyston) crops out, and extends northward to the Allegheny Plateau, some distance north of Kittatinny (Blue) Mountain. The Lehigh River flows along or close to the southern boundary between Allentown and Easton. Saucon Valley and some minor valleys contiguous to the Delaware River constitute portions of this province infolded or infaulted into the Reading Prong Province. Chestnut Hill, Camels Hump and Rittersville Hill are outliers of the Reading Prong.

The strata in this province in Pennsylvania range in age from Lower Cambrian to Pennsylvanian. In the area discussed in this Guide, the youngest formation of consolidated rocks is the Shawangunk of Kittatinny (Blue) Mountain of Silurian age. Of course, the glacial and alluvial deposits are much younger.

[1] Fenneman, N. M.: *Physiography of Eastern United States.* 714 pp., New York, 1938.

The most extensive and most important unit of the Province in this section is the Great Valley which is underlain by limestones in the southern part and by shales and slates in the northern part. Here are located most of the towns and cities of the region and here is where the major industrial plants have been constructed.

Kittatinny (Blue) Mountain, bounding the Great Valley on the north, appears as a great even wall when viewed from a distance. Locally it is deeply notched by the Delaware and Lehigh Rivers and by several shallow cuts formed by once existent streams long since diverted to other courses, leaving their old valleys as wind gaps. These water gaps and wind gaps have long attracted attention.

Reading Prong of the New England Province. South Mountain and other similarly trending hills, composed almost entirely of pre-Cambrian metamorphic rocks, constitute the Reading Prong of the New England Province. This province is in line with the Blue Ridge Province which begins in southern Pennsylvania and extends southward to Georgia. The two provinces are separated by a gap of about 50 miles.

In the Lehigh Valley the Reading Prong comprises practically all the area between the Lehigh River and the band of Triassic strata.

Triassic Lowland of the Piedmont Province. The southern portion of our area belongs to the Triassic Lowland. It is mainly a region of low hills and valleys underlain by Triassic shales and sandstones, predominantly red in color. In places it is interrupted by ridges composed of extrusive and intrusive dark-colored basic rocks generally called "trap." Some of these trap ridges rise to the height of the hills of pre-Cambrian rocks of the Reading Prong.

Peneplanes. One of the live controversial problems of the region is that of the number of peneplanes present. There is general agreement that the even crest of Kittatinny (Blue) Mountain was produced by erosion and that it is the remnant of a former extensive peneplane. It was named the Kittatinny peneplane when it was regarded as distinct from the elevations lying to the south of the Great Valley. The tops of these latter hills were designated at an earlier date as the Schooley peneplane. The most common view now held is that the two are the same and therefore both are portions of the Schooley peneplane which has a greater elevation on the north side of the Great Valley. In fact, all the peneplanes of eastern Pennsylvania seem to slope in the direction taken by the major streams.

The Schooley peneplane on the top of Kittatinny (Blue) Mountain has been cut in hard resistant Silurian sandstones and conglomerates with a prevailing steep northwest dip. Although the individual beds are unlike in composition, the top of the mountain presents an unexpected plain-like aspect. The same peneplane on the tops of the hills of the Reading Prong has been so greatly modified by differential erosion of the pre-Cambrian rocks that there are few places in this region where it closely resembles a plain. The peneplane on Kitta-

tinny (Blue) Mountain has a general altitude of 1,400 to 1,600 feet, and on the hills of pre-Cambrian rocks in the Reading Prong it is from 800 to 1,000 feet.

The tops of the slate hills lying south of Kittatinny (Blue) Mountain rise to a fairly uniform altitude of 700 to 900 feet. This surface has been named the Harrisburg peneplane and generally interpreted as more recent than the Schooley peneplane. George H. Ashley[2] regards this surface as a part of the Schooley which has been more extensively lowered by erosion on account of the less resistant character of the slates as compared with the Silurian siliceous rocks.

A third erosion surface appears in the limestones of the Great Valley. The major portions of Allentown and Bethlehem have been built on it. This has been termed the Somerville peneplane. It has extensive flat areas rising to about 400 feet.

Ashley regards this also as a portion of the Schooley peneplane lowered to a greater extent than in the slate hills. F. Ward[3] has suggested that this is a portion of the Harrisburg peneplane reduced to a lower level by solution of the limestones.

Regardless of the interpretation, these plane surfaces in the Lehigh Valley are conspicuous features which are readily recognized.

GEOLOGIC FORMATIONS OF THE LEHIGH VALLEY

Geologic history is deciphered by the type of rocks that were formed at successive stages. The columnar section shows the different formations represented in the area. The descriptions which follow start with the oldest known rocks.

Pre-Cambrian Rocks

The pre-Cambrian rocks everywhere throughout the district have been so greatly metamorphosed that there is considerable difficulty in determining their original character and the relationship of the different formations. As might be expected, different interpretations have been offered by the various workers. These can be discussed in only a general way in this report. The author and his associates have divided these ancient rocks of the region into the Franklin, Moravian Heights, Pochuck and Byram formations in order of assumed age from oldest to youngest.

Franklin formation. The Franklin formation includes the oldest rocks exposed in the Lehigh Valley. It is probably to be correlated with the Grenville formation of New York and eastern Canada. It is primarily a highly metamorphosed, coarsely crystalline limestone in which all traces of bedding planes have been obliterated. It is best known from Franklin Furnace, New Jersey, where it contains the unique zinc ore deposit known to all mineralogists for its unusual

[2] Ashley, George H., Studies in the Appalachian Mountain sculpture: Geol. Soc. Am. Bull., vol. 46, pp. 1395-1436, 1935.

[3] Ward, Freeman, The role of solution in peneplanation: Jour. Geol., vol. 38, pp. 262-270, 1930.

minerals. The limestone ranges from high to low magnesian content or from pure limestone to dolomite. A prominent characteristic is graphite in small flakes irregularly distributed through the limestone, mainly in unoriented positions. Another phase of the Franklin formation is a graphitic quartz schist which elsewhere in Pennsylvania has been worked for graphite.

This formation is represented sparingly in the region. The two principal occurrences are in Chestnut Hill, where there are fine exposures along both the Delaware River and Bushkill Creek, and in the western continuation of the Pine Top-Camels Hump prominence with exposures near the right bank of Monocacy Creek. In Chestnut Hill much of the limestone has been converted into serpentine and talc.

The thickness of the formation is unknown but it does not seem to be over 200 feet and perhaps is considerably less. No fossils have ever been found in it. If it every had any they were destroyed during the process of metamorphism.

There is difference of opinion in regard to the correlation of the formation. This Survey has placed it in the Archean, correlating it with the Laurentian of Canada, whereas the U. S. Geological Survey correlates it with the Huronian of the Algonkian.

Moravian Heights formation. What was originally a series of shaly sandstones has been metamorphosed into light green, crudely-laminated rocks containing much sericite and sillimanite. These beds are designated the Moravian Heights formation. They were first recognized near Bethlehem but later found in other localities throughout the belt of pre-Cambrian rocks of the Reading Prong. Some of the rock resembles talc and was at one time quarried as "soapstone" and used as a paper filler and for furnace lining. Some of the best occurrences of this formation are in the east end of Chestnut Hill, the southeast slope of Morgan Hill, about half a mile west of Wydnor, and other areas about 4 miles east and about 6 miles southeast of Bethlehem.

The rocks of this series have been intruded with abundant igneous matter so that in places they are scarcely recognizable. The thickness is indeterminate but, where not increased by intrusives, is probably only a few hundred feet.

Pochuck gneiss. The dark-colored basic gneiss so prominently developed in the hills of the Reading Prong in the southern part of Northampton County has been named the Pochuck gneiss. It commonly shows marked gneissic banding which is accentuated where it has been invaded by granite.

The dark color is due to the great abundance of hornblende and, in places, to biotite and pyroxene. The feldspars are oligoclase-andesine and labradorite plagioclases. Magnetite, epidote, quartz, garnet and titanite are common accessory minerals. Basic pegmatites are noticeable in different places. The Pochuck is now believed to have been entirely igneous originally although previous investigators have regarded it as partly sedimentary.

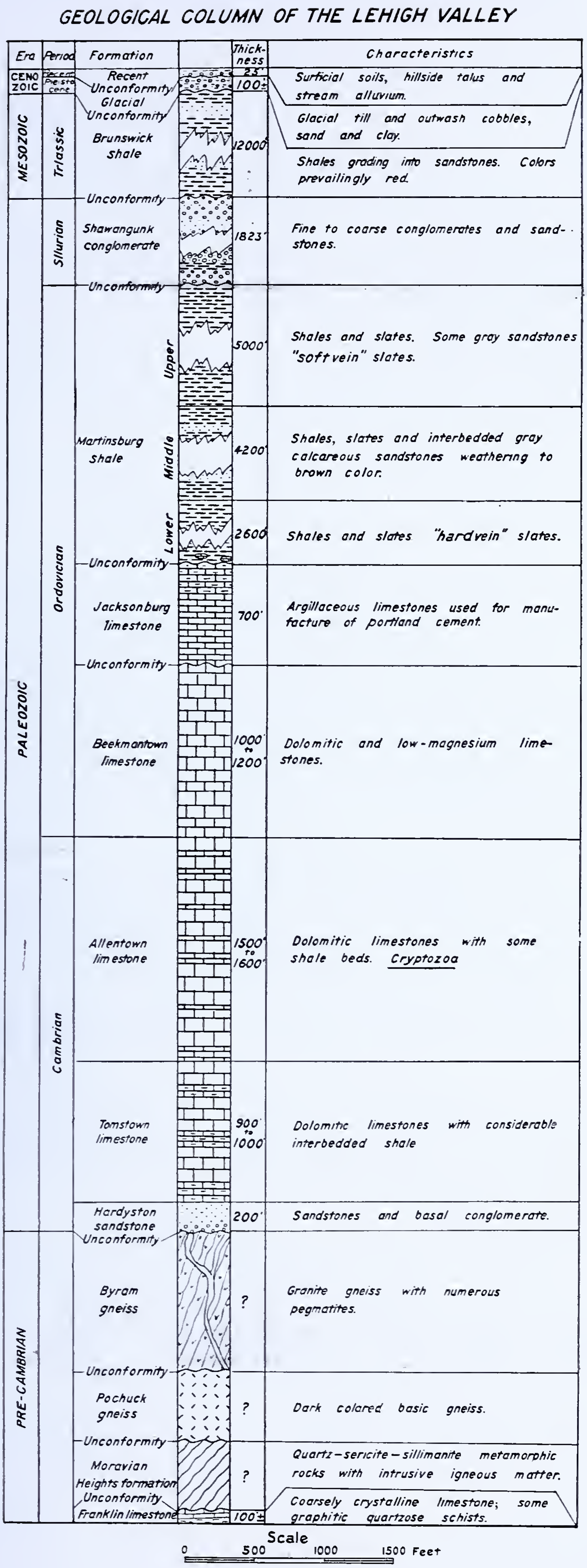

Figure 1. Geological column of the Lehigh Valley.

The top of the famous Hexenkopf Hill is composed of Pochuck gneiss.

Byram gneiss. The most widespread type of metamorphic rock in the region is the Byram gneiss. Originally a granite, it has been metamorphosed to a granite gneiss. Prominent gneissic banding is typical. This formation is later than the other rocks of the pre-Cambrian hills, as shown by the fact that it has cut and injected each of the other formations of the pre-Cambrian series.

In contrast with the Pochuck gneiss, the Byram is light-colored except in occasional dark streaks that apparently represent concentration of the ferromagnesian minerals in bands during metamorphism, or inclusions of the Pochuck.

The Byram has a great range in mineralogical composition. The most abundant minerals are orthoclase, quartz and hornblende. It also ranges from fine to coarse crystalline material.

Pegmatites. Throughout the gneiss areas pegmatites are common. Loose fragments occur in the hillside talus. They are generally granitic and associated with the Byram gneiss. In the Byram areas they consist mainly of coarse feldspar and quartz but in the Pochuck they contain large crystals of hornblende. Recently an occurrence of pegmatite cutting the Hardyston sandstone has been found at the base of the northeast corner of Morgan Hill along a former electric railway. It seems, therefore, that the pegmatites of the region are not all of the same age. Although most of them probably were formed during or closely following the Byram invasion, some of them are younger than Lower Cambrian.

Paleozoic Rocks

Paleozoic strata underlie most of the Lehigh Valley. They are sharply separated from the pre-Cambrian rocks by the relatively less metamorphism which they have undergone. All evidence points toward an enormous time-gap between the two series of rocks resulting in a wide-spread unconformity.

The strata considered in this Guide range in age from Lower Cambrian to Silurian and consist of sandstones, conglomerates, shales and limestones. The only igneous rocks of this era known in the region are the few pegmatites previously mentioned.

In general one crosses formations of decreasing age in going north from the hills of pre-Cambrian rocks, although there are some exceptions, owing to complicated folding and faulting of the strata.

Hardyston formation. The Hardyston is mainly composed of conglomerates and sandstones. In places the sandstone has been converted into quartzite or jasper. The basal layers in most places are conglomeratic, consisting of quartz pebbles stained a pale wine-red and embodied in a dark-colored argillaceous matrix. Between the gneiss and the conglomerate a thin layer, up to ten inches in thickness, of dirty olive-green, fairly homogeneous pinite is present in some localities. It is believed to represent the soil that formed on the surface of the gneiss before the deposition of the Hardyston sediments.

Sandstones, commonly containing arkose or even fresh pieces of feldspar, constitute most of the formation. Some of the finer-grained varieties have been converted into quartzite or into ferruginous taffy-yellow jasper which in turn passes into limonitic iron ore. Pyrite is a common constituent of the unweathered sandstones. Close to the bedding and joint planes it has been oxidized to hydrated iron oxide, staining the surfaces brown, yellow or red. Architects prefer these colored blocks rather than the gray fresh stones for buildings.

The Hardyston probably at one time covered the pre-Cambrian gneisses throughout the entire area. It has now been removed by erosion over the tops of the gneiss hills. Most of its outcrops are along the lower slopes of these ridges. They are covered with talus and are seldom seen except in building stone quarries and iron ore mines.

Worm borings, *Scolithus linearis,* are the only fossils yet found in the Hardyston in this region.

The Hardyston of the Lehigh Valley ranges in thickness from a few feet to about 200 feet.

Tomstown formation. Conformably overlying the Hardyston is the Tomstown dolomite. Massive, compact beds up to ten feet in thickness, thin-bedded argillaceous layers, and interbedded sericitic shales are all to be seen in some of the quarries or in natural outcrops. The abundance of shale distinguishes the Tomstown from the other limestones of the district.

The Tomstown is more abundant as a surface rock in the vicinity of the Lehigh River and in the intermontane limestone valleys in the Reading Prong physiographic province. Its present surficial distribution has been brought about by complicated folding and faulting followed by extensive erosion.

Quartz gash veins, segregations of black flint, oolites, edgewise conglomerates, ripple marks, and cross bedding are abundant in the Tomstown in some localities.

No recognizable fossils have been found. The thickness has not been definitely determined but seems to be 900 to 1,000 feet.

Allentown formation. The Allentown dolomitic limestones are widespread in the Lehigh Valley, mainly north of the Lehigh River. They are normally dense bluish-gray rocks high in magnesia content. Surfaces long exposed to the weather commonly show alternating layers of light and moderately dark stone, a feature seldom evident in the limestones above and below the Allentown.

Some shaly bands are present, but generally they are thin. The bedding planes commonly are covered with a thin film of glistening flakes of sericite. Oolites, ripple marks, black flint, quartz veins and grains of clear quartz sand in the dolomite occur in many places.

Heads of calcareous algæ, *Cryptozoon,* both large and small, are conspicuous and constitute the most diagnostic feature of the forma-

tion. These fossils are doubtfully present in Tomstown and Martinsburg dolomites.

The thickness of the Allentown formation is 1,500 to 1,600 feet. Complicated structure and lack of continuous exposures prevent exact measurement.

Figure 2. Alternating light and dark beds of dolomitic limestones, fairly typical of Allentown limestone. The lightest bed contains Cryptozoa.

Beekmantown formation. The band of Beekmantown limestones and dolomites that extends through the Lehigh Valley in a northeast-southwest direction is mainly confined to the northern part of the limestone belt. Few exposures are present south of Camels Hump and Chestnut Hill. Small detached areas such as occur in the Saucon Valley, in West Easton and near Portland have been faulted into their present positions.

Lithologically, the Beekmantown is composed of limestones in which the magnesian content ($MgCO_3$) ranges in the alternating beds from a few percent to over 40 percent. In the upper portion of the formation some layers are sufficiently low in magnesia to be used in the manufacture of portland cement. Such stone is lacking in the older limestones. Some shaly beds are present, but they are less than in the Allentown and Tomstown formations. Many weathered beds show conglomeratic character, a feature seldom recognized in the fresh rock. On the weathered surfaces bluish-gray portions may form pits and brownish-gray sandy patches form low prominences.

Fossils are not abundant, but have been found in several places. Crinoid stems are most common, but several species of coiled and straight mollusca are present.

The Beekmantown in the Lehigh Valley ranges from 1,000 to 1,200 feet in thickness. Oolites, edgewise conglomerate, black flint, and gash veins of quartz and calcite are present. The veins are confined mainly to the more highly magnesian beds.

Jacksonburg formation. The Jacksonburg argillaceous limestones crop out in a continuous band from the Delaware River near Belvidere, N. J., to Northampton on the Lehigh River. Westward the formation appears at the surface in Lehigh and Berks counties in detached areas. Isolated areas occur also in the Saucon Valley, along Monocacy Creek north of Camels Hump, and near Portland. These rocks underlie or pass near the villages of Martins Creek, Stocker-

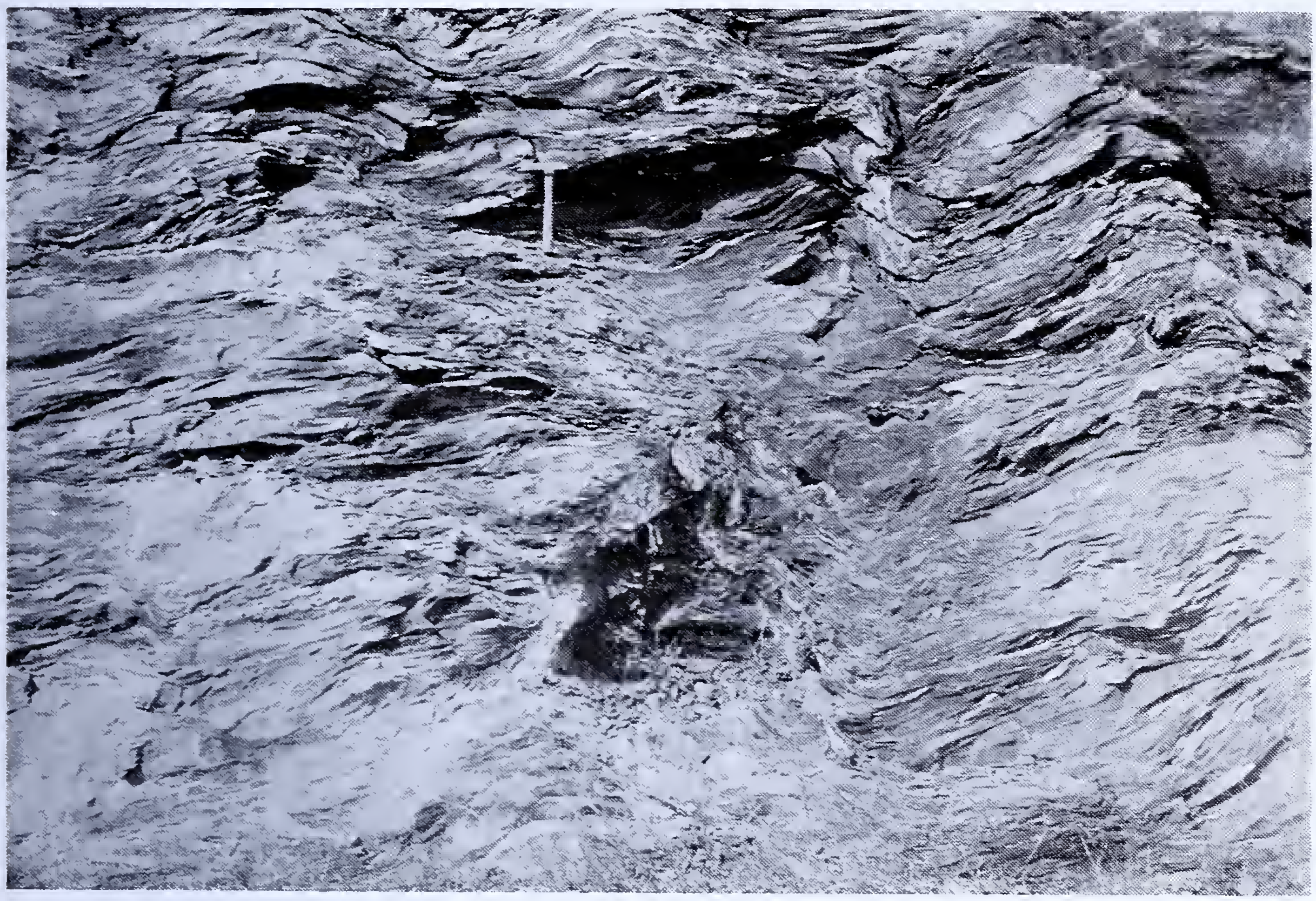

Photo by J. M. Lohse.

Figure 3. Crumpled Jacksonburg cement rock. The thin beds of argillaceous limestones are weak and yield to compressive forces in this manner. Cavities between the beds are filled with veins of calcite and quartz.

town, Nazareth, Bath, Northampton, Cementon, Coplay, Ormrod and Fogelsville, all of which owe their existence mainly to the portland cement industry.

In position, in lithologic character, and in chemical composition the Jacksonburg is intermediate between the Beekmantown limestones to the south and the Martinsburg shales and slates to the north. In some places topographic distinctions can be noted. Owing to somewhat greater resistance to erosion, the band of outcropping Jacksonburg stands noticeably higher than the adjoining Beekmantown. It is less resistant than the Martinsburg, so that the contact of the two is at the foot of a prominent escarpment.

The Jacksonburg in many places can be fairly definitely divided into two members, the lower locally called "cement limestone" and the upper "cement rock." In other places the two varieties may both be present, but interfinger intricately or the "cement limestone" facies may occur as beds or lenses in the "cement rock." In still other localities the "cement limestone" is not recognized.

The lower member is a high-grade, soft, gray, pure crystalline limestone. Some analyses show more than 95 percent $CaCO_3$. The beds generally are fairly massive. On weathered surfaces they are seen to be highly fossiliferous. Crinoid stems are most abundant, but many other forms are present.

The upper member is better developed and much more persistent. It is a black argillaceous limestone that may sometimes be mistaken for slate. It occurs in thin beds, is compact, and breaks with a conchoidal or splintery fracture. In the lower portion it is apt to contain about 75 percent calcium and magnesium carbonates; the balance is silica, aluminum silicate and iron oxide. The magnesium carbonate is always small in amount. The upper beds, close to the Martinsburg, generally are lower in carbonates.

Fossils occur in the "cement rock" facies, but are generally more fragmental than in the "cement limestone."

A few thin beds of bentonite (altered volcanic ash) are present in the Jacksonburg limestones in the vicinity of Nazareth.

Ralph L. Miller[4] reports the following fossils from the Jacksonburg in the eastern part of Northampton County.

Prasopora orientalis
Receptaculites occidentalis Salter
Pachydictya acuta, Hall
Rhinidictya sp. cf. R. mutabilis Ulrich
Lingula elongata
Sowerbyella sp.
Parastrophina hemiplicata (Hall)
Rafinesquina alternata (Conrad)
Strophomena sp.
Dalmanella rogata (Sardeson)
Dinorthis pectinella
Zygospira sp.
Mesotrypa sp.
Calliops callicephalus (Hall)
Calymene sp.
Isotelus fragment
Conularia
Pelecypod indet.

In thickness the Jacksonburg ranges in the Lehigh Valley from less than 200 feet near the Delaware River to about 700 feet near the Lehigh River.

The Jacksonburg limestones were the first materials to be used for the manufacture of portland cement in the United States and their extensive development in the Lehigh Valley has made the "Lehigh District" the most important cement region of the country. More than 500 million barrels of cement have been made in Northampton County and sold for more than 600 million dollars. The production in Lehigh County is considerably less.

[4] Geol. Soc. America Bull., vol. 48, pp. 1687-1718, 1937.

Martinsburg formation. The Martinsburg formation consists mainly of shales or slates, but includes fairly abundant interbedded sandstones and minor amounts of dolomitic limestones. All the recent workers in the region have recognized different members of the Martinsburg. The writer[5] and C. H. Behre, Jr.,[6] claim that there are three members, as will be described here, but G. W. Stose[7] believes that there are only two members. What Miller and Behre designate as the third or upper member, Stose claims is the repetition of the lower member.

The lower member unconformably overlies and crops out in a band immediately north of the Jacksonburg formation. It consists almost entirely of shales which have generally been metamorphosed to slates. The beds contain considerable carbonaceous matter and, when fresh, are dull black. On weathering the beds become gray to buff and break into thin elongated fragments.

This member includes beds of workable slate which have been quarried extensively near Chapmans and Belfast. The slate is known as the "hard vein" slate in distinction from that of the upper member. The original beds were thin and contained certain highly siliceous layers. The cleavage blocks thus contain numerous thin "ribbons" that are especially prominent on weathered surfaces.

In the vicinity of Seemsville and Dannersville there are several lenses of massive dolomitic limestone near the base of the formation. Grayish sandstones that weather to a yellowish brown are present, but less than in the overlying member.

The middle member contains some argillaceous beds which have yielded some poor slate, but in the main it consists of sandy shales and sandstones. Most of the sandstones are gray when fresh and contain some calcareous cement. The weathered limonitic brown beds lack this binder. Conglomerates are present locally, with individual pebbles up to an inch in diameter.

The upper member of the Martinsburg is similar to the lower member with the important distinctions that it contains no limestones and the ribbons in the slates are less abundant, thicker, and are not sandy. The slate of this member, quarried in scores of places about Bangor, Pen Argyl, Wind Gap, Danielsville, Slatington, etc., is known in the market as the "soft vein" slate because it is so much softer than that of the lower member. Whereas the sandy ribbons of the "hard vein" slate do not interfere with its use, the ribbons of the "soft vein" slate are highly carbonaceous, commonly contain some pyrite, and weather so readily that much of the ribboned slate must be discarded. If the ribbons were as common in the "soft vein" as in the "hard vein" material, certain profitable quarries could not be operated.

[5] Allentown Atlas of Pennsylvania, No. 206, Allentown Quadrangle; Pennsylvania Topog. and Geol. Survey, 1925.

[6] Slate in Pennsylvania: Bull. M16, Pennsylvania Topog. and Geol. Survey, 1933.

[7] Stose, G. W., Unconformity at the base of the Silurian in southeastern Pennsylvania: Geol. Soc. America Bull., vol. 41, pp. 629-658, 1930.

The thickness of the Martinsburg is still one of the disputed geological problems of the Lehigh Valley. The complicated folds and faults and the absence of key beds that can be identified in discontinuous exposures, as well as the question of two or three members, are responsible for the wide variation in the estimates of thickness. Behre estimates the thickness of the three members respectively as about 5,000, 4,200 and 2,600 feet. Stose suggests a thickness of 3,000 feet for the entire Martinsburg. Behre and other workers appreciate the possibility of unrecognized isoclinial folded beds that may cause the estimates to be too high. The problem is as yet unsolved.

Fossils are scarce and in general poorly preserved. Most of those collected were found in the middle sandy member. E. O. Ulrich has identified the following forms:

Zygospira modesta
Dalmanella cf. multisecta
Sowerbyella sericea
Hebertella sinuata
Plectorthis cf. plicatalla
Rafinesquina aff. camerata
R. cf. alternistriata
R. centrilineata (?)
Strophomena spec. nov.
Ctenodonta aff. levata
Sinuites aff. cancellatus
Lophospira aff. obliqua
Tetranota rugosa
Liospira aff. progne
Lepidocoleus jamesi
Aparchites (?) sp.
Ctenobolbina ciliata
Calymene sp.
Proetus sp.

Figure 4. Typical pile of quarry waste about a slate quarry. Chapman Quarries.

The slate quarries in the Martinsburg formation of the Lehigh Valley have been in continuous operation for over 100 years. In Northampton County alone nearly 200 quarries have been worked at differ-

ent times, and in Lehigh County more than 100. The Lehigh Valley contains the principal slate region of the entire United States. Some of the quarries are large, as evidenced both by the huge piles of waste slate and the large dimensions of some of the openings. The deepest quarry is 700 feet. The industry at present is experiencing a serious depression.

Shawangunk formation. Kittatinny (Blue) Mountain, the dominating topographic feature of the Lehigh Valley, is composed of the Shawangunk formation. Coarse siliceous sandstones and conglomerates constitute the materials that have resisted erosion better than

Figure 5. White quartz and black flint pebbles in Shawangunk conglomerate, south side of Kittatinny (Blue) Mountain near Little Gap.

any other rocks of the entire region. The formation includes some fine-grained greenish-gray sandstones and thin strata of black shale. An erosional unconformity separates the Shawangunk and the Martinsburg.

Great blocks of the Shawangunk have rolled down the slopes of the mountain and form thick talus heaps that largely conceal the contacts with the underlying and overlying strata.

The lower part of the Shawangunk was called the Oneida conglomerate and the upper portion the Medina sandstone by the Second Geological Survey of Pennsylvania.

The fossil fucoid, *Arthrophycus harlani*, has been found along the road just south of Little Gap. Clarke and Ruedemann[8] have described the following eurypterid fossils from a few thin carbonaceous slate beds outcropping in the Delaware Water Gap section.

Dolichopterus otisius Clarke
Eurypterus maria Clarke
Stylonurus cf. myops Clarke
Hughmilleria shawangunk Clarke
Pterygotus cf. globiceps Clarke & Ruedemann

The Shawangunk in this section is about 1,800 feet in thickness.

Figure 6. *Arthrophycus harlani* in Shawangunk sandstone along roadside on south slope of Kittatinny (Blue) Mountain near Little Gap.

Mesozoic Rocks

Brunswick formation. Bordering the Lehigh Valley on the south is a broad belt of sandstones and shales belonging to the Brunswick member of the Newark series of Triassic age. The belt is about 30 miles wide where it crosses the Delaware River. The strata are chiefly red or reddish brown, but in certain places black or dull green. Coarse conglomerates occur along the northern border in several areas. The pebbles and cobbles are mainly quartzites embedded in a matrix of feebly-cemented red mud or shale. In a few places limestone pebbles are abundant. Flint Hill, located at the junction of Bucks, Lehigh and Northampton counties, is composed of these conglomerates.

[8] New York State Museum, Memoir 14, pp. 417-418, 1912.

The disintegration of the matrix has left the cobbles on the surface, thus forming a very stony soil.

The total thickness of the Brunswick formation is about 12,000 feet, but the greater portion lies beyond the limits of the region discussed here.

The Brunswick strata are nearly horizontal or dip gently northwest. There is a great hiatus between the Triassic and the underlying rocks on which they rest unconformably.

The Triassic sedimentary rocks in the Eastern States have been intruded by diabase and basalt. The Palisades of the Hudson River are the best known occurrence. These rocks occur on the south border of the Lehigh Valley and constitute the most recent igneous rocks of the eastern part of the United States. Haycock Mountain, the Ringing Rocks below Riegelsville and hills in the vicinity of Coopersburg represent this period of igneous activity.

Pleistocene and Recent

Glacial deposits. It is believed that at three different times during the Glacial period, tongues of ice from the great continental ice sheet were pushed southwestward into the Lehigh Valley. These three invasions are designated by Leverett[9] in order of age as the Jerseyan, Illinoian and Wisconsin.

The first or Jerseyan ice advanced to the Schuylkill River near Shoemakersville. Deposits made at that time have been largely removed so that our information concerning that advance is scanty. The Illinoian extended in the Lehigh Valley to Trexlertown and Slatington and sent a prong of ice into the Saucon Valley. The deposits are seldom more than ten feet thick, although in West Bethlehem, northeast of Allentown, near Georgetown and in South Easton the glacial till and sorted gravels deposited in previous depressions are locally as much as 40 feet thick. Terminal morainal topography is developed east of Trexlertown and in the eastern part of the Saucon Valley. The ice-borne boulders gathered by farmers from their fields can be studied in the stone piles along the boundary fences.

The last glacial invasion of the Lehigh Valley was by the Wisconsin ice sheet. It advanced only a short distance beyond Bangor, although the outwash gravels and sand extend far down the Delaware River valley. Irregular hills of till and stratified gravels and sand characteristic of terminal moraine topography are prominent features of the northeast end of the Lehigh Valley. The kames along Jacoby Creek, extensively worked for sand and gravel, are conspicuous and contain a great variety of stones from many different formations outcropping to the northeast.

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[9] Leverett, Frank, Glacial deposits outside the Wisconsin terminal moraine in Pennsylvania: Pennsylvania Topog. and Geol. Survey Bull. G7, 123 pp., 1934.

Figure 7. Working a Wisconsin kame deposit along Jacoby Creek, northwest of Mt. Bethel The gravels and sands are rudely stratified.

Recent alluvium. Both the major and minor streams of the Lehigh Valley are engaged in erosion and deposition in different parts of their courses. The alluvial deposits have accumulated in the stream channels and on the flood plains. In few places are these deposits either thick or widespread. They consist mainly of mud, silt and sand. Along the Lehigh River anthracite particles washed from the culm banks of the Hazleton region are abundant in the alluvium.

Soils. Most of the different kinds of soils in the Lehigh Valley are of residual origin and bear a close relationship to the underlying rocks from which they were formed. Plant humus has mixed with the residual soil and to a lesser extent with glacial debris and talus. In general, the limestone soils are fine-grained and clayey, the slate soils are filled with thin fragments of weathered slate, and the soils of South Mountain and Kittatinny (Blue) Mountain are sandy or stony.

GEOLOGICAL STRUCTURE

The generalized structure of the Lehigh Valley is as simple as the detailed structure is complex. In general, the pre-Cambrian rocks constitute the core of the South Mountain ridges. Proceeding from these ridges northward across the valley, one encounters the outcrops of progressively younger strata of Cambrian, Ordovician and Silurian age, each formation disappearing beneath the next younger, owing to the prevailing north-northwest dip.

Examination of the detailed structural features reveals complicated folds and faults, great and small and of all sorts. Normal and reverse

faults from those of microscopic displacement to movements of several thousand feet are abundant. Many have been located and scores or hundreds of additional ones probably are concealed beneath the soil, terrace and talus overburden. Open, closed, monoclinal, isoclinal, asymmetric and overturned folds exist almost everywhere in the strata of the Lehigh Valley. It is unusual to find any horizontal beds in the Paleozoic strata. These complicated structures greatly modify the generalized structures mentioned above. For example, Cambrian and Ordovician rocks are down-folded or down-faulted or both in narrow valleys between ridges of pre-Cambrian gneisses. Formations that have in the main disappeared beneath the next younger formations may be brought to the surface in local anticlinal folds.

The large faults also modify locally the regular order of outcrop of the formations. The best example occurs near Lanark in the Saucon Valley, where a small area of Jacksonburg has been faulted down into contact with the pre-Cambrian gneiss, although the two are stratigraphically several thousand feet apart.

Returning to generalization, the trend of both faults and folds is northeast to southwest or in places almost east-west. Local exceptions, however, are numerous and trends can be found in every direction, especially those of minor deformations.

Stose and Jonas[10] suggest that South Mountain is part of a great overthrust mass of pre-Cambrian gneiss pushed from the southeast over the Cambrian sandstones. This view is not accepted by the author, who, in collaboration with D. M. Fraser, has discussed the problem.[11]

HISTORICAL GEOLOGY

A short description of the successive geologic events that have taken place in the Lehigh Valley may be of interest to local investigators.

The story of pre-Cambrian conditions is somewhat indefinite. The order of succession of geologic units given in the geological column is not known positively. These old rocks have been so greatly changed by metamorphosing agents that there is considerable doubt as to their original character. Any fossils originally present have been destroyed. The two sedimentary formations—Franklin and Moravian Heights—exist in only small amounts in comparison with the igneous rocks, the Pochuck and Byram. We, therefore, conclude that igneous activity was intense during the pre-Cambrian. Erosion intervals of vast extent probably separate the formations from each other and from the overlying Cambrian deposits. Information is meagre as to the configuration of the continent during the pre-Cambrian.

During the whole of the Cambrian, Ordovician and Silurian periods a great inland sea occupied the area of the present Lehigh Valley. Sediments were carried into it by streams from a land mass, Appalachia. The sea was shallow at all times, as shown by the abundant

[10] Stose, G. W., and Jonas, A. I., Highlands near Reading, Pennsylvania: Geol. Soc. America Bull., vol. 46, pp. 757-780.
[11] Geol. Soc. America Bull., vol. 46, pp. 2031-2038.

ripple marks, sun cracks, oolites, edgewise conglomerates, and cross-bedding. Nevertheless, within this sea thousands of feet of sediments accumulated due to the sinking of the sea bottom as deposition took place. It should not be concluded, however, that the accumulated weight of the sediments was the sole or even the main cause of the subsidence.

The changing character of the deposits probably was due to several causes, of which the variation of the gradients of the land streams probably was the most important. When the continental land mass was elevated, the stream gradients were high, and the streams swift, the sea received coarse water-worn materials such as occur in the base of the Hardyston and in the Shawangunk. When the force of the streams was slightly reduced, sands were laid down. The sandstones of the Hardyston, Martinsburg and Shawangunk represent this phase. When the streams were only powerful enough to transport fine mud particles, the argillaceous deposits accumulated, as represented by the Martinsburg shale and slate. During most of Lower Paleozoic time practically no suspended material was brought into the sea. Instead, the streams bore dissolved matter mostly, perhaps largely carbonates of calcium and magnesium. The deposits formed then constitute the limestones and dolomites of the valley. Whether the deposition was caused by organic (biological) or inorganic (chemical and physical) agencies or by both classes is still a debatable question. The scarcity of fossils may be regarded as favoring the predominant action of inorganic forces, although it is well to recall that low forms of organisms, such as bacteria, may have caused the deposition of the carbonates without leaving any traces of the organisms themselves.

The unconformities as shown in the geologic column represent interruptions in deposition by earth disturbance which temporarily caused the sea to disappear and permitted erosion to take place. One of the most pronounced unconformities of the Paleozoic is between the Martinsburg and the Shawangunk formations. It was caused by crustal deformation at the close of the Ordovician and is called the Taconic Disturbance.

The Appalachian Revolution closed the Paleozoic era and obliterated the old inland sea that had existed for millions of years. Since then practically all of the Lehigh Valley has been land continuously. During this time probably 20,000 to 40,000 feet of material have been removed by erosion.

During both major periods of deformation of the region, folding and faulting of the strata took place. Although it is generally assumed that the Appalachian Revolution, which was much more widespread, caused most of the structural complications, there are indications that the Taconic Disturbance may have been of approximately equal importance.

The Brunswick deposits were laid down in a structural trough or elongated basin which extended from the Hudson River to Virginia

during the Triassic period. Igneous action in the form of diabase and basalt intrusions and surface lava flows was intermittent during and following the deposition of thousands of feet of shales, sandstones and conglomerates.

The Ice Age in the Lehigh Valley was of only minor significance in comparison with the events of earlier periods. Although for thousands of years the climate undoubtedly was modified by the three incursions of tongues of glacial ice, the existing records of this time of refrigeration are slight.

The geologic agents of destruction that have been active during the past are all at work today. Chemical processes of rock decomposition and solution—oxidation, carbonation, hydration and solution—are all engaged in rock destruction. The physical forces of frost, gravity and running water act in conjunction with the chemical processes. Evidences of these agents can be seen everywhere. Most of these agents work so slowly that they are largely overlooked by most people. Eventually the Lehigh Valley will be reduced to a low featureless plain and the present name no longer applicable, but always provided that no deformations take place to hinder or counteract. How long before such a condition is reached depends upon so many variable factors that it is needless to attempt to reduce the time to years. Future generations, if the human race does not itself pass off the stage by suicide or by its inability to cope with other forms of life or by changing physical conditions, will see a greatly modified Lehigh Valley. They will be either enjoying the fruits of former periods or deprived of certain things which we now have, perhaps due to exhaustion. This field of speculation is fascinating and never-ending.

ECONOMIC GEOLOGY

A full discussion of the economic mineral resources of the Lehigh Valley scarcely falls within the scope of this bulletin. Certain of the products are mentioned in the preceding pages and others in the itineraries. For descriptions of all the various economic products of the region, reference is made to the forthcoming volumes on Northampton and Lehigh counties and to the published report on the Mineral Resources of the Allentown Quadrangle.[12] However, a brief statement concerning the economic geology may be helpful.

Among the metallic economic products, the iron ores are of major importance. They were mined by open-cut and underground workings in a few hundred places in the Lehigh Valley, but at present not a single mine is in operation. The limonite ores were most extensively mined. They occur in the limestones and in the Hardyston sandstones. Next in importance are the magnetite ores of the pre-Cam-

[12] Miller, B. L., Atlas of Pennsylvania, No. 206, Allentown Quadrangle, Pennsylvania Topog. and Geol. Survey, 1925.

brian gneisses. Some carbonate (siderite) and some pyrite ores were found in association with the limonite ore.

The Friedensville zinc deposit in the Saucon Valley is the other metallic ore that has been mined in the district. Manganese and copper minerals are present in different places, but are of no commercial significance.

The non-metallic economic products are of far greater value. The cement rock of the Jacksonburg formation has promoted the establishment of the various cement plants which have contributed so largely to the prosperity of the Lehigh Valley. The other limestones are utilized extensively for the manufacture of lime, for flux, and for crushed stone. Building stone is obtained from the Hardyston

Figure 8. Quarry in Hardyston sandstone, north slope of South Mountain between Allentown and Bethlehem. Stone breaks readily into rectangular blocks.

sandstone, the gneisses and the limestones. The Triassic diabase furnishes monumental stone. The slate of the Martinsburg is quarried mainly for roofing material, but also for structural and blackboard slabs and for school slates. The surficial clays of both residual and glacial origin are burned for brick. Glacial deposits are worked for sand and gravel as well as some of the decomposed gneisses. Ocher and umber have been dug in a few places. Graphite and mica deposits have been prospected, but never worked.

The soils of the Lehigh Valley belong to several types and are suitable for a wide variety of agricultural products. The underground water resources are drawn upon in all sections.

Figure 9. Quarry in Hardyston sandstone, north slope of South Mountain between Allentown and Bethlehem. The dip of the beds is the same as the slope of the hill, constituting a dip slope, in some places. In other places the strata dip to the north at higher angles than the slope of the hill.

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DETAILED ITINERARIES

Itinerary 1. Bethlehem to Coopersburg

Miles

0.00 Lehigh River—Hill-to-Hill-Bridge. Proceed southward on Route 12 (Philadelphia road).

1.4 Cut in typical Byram gneiss near crest of South Mountain. Banding prominent in portions; gradations from fresh rock upward to soil; bands of basic rock (dikes or Pochuck gneiss inclusions), one especially prominent on east side of highway 3 to 4 feet in thickness. Several slickensided surfaces coated with fibrous amphibole.

1.65 Take right hand fork—Old Friedensville road.

1.9 Seidersville. Small abandoned quarry in Hardyston sandstone, west side of road, in rear of house occupied by Ray Dubbs (October, 1938). This is one of the few exposures of Hardyston in place on the borders of Saucon Valley.

2.35 Wydnor. Side trip not included in mileage. Turn right (west) at crossroads. Follow highway about half a mile, where it turns south. Continue westward on private road. Park car at residence and climb hill to northwest. Near summit are two old pits in quartz-sericite-sillimanite schist. Material was once quarried in belief it was talc. Belongs to the Moravian Heights formation.

3.2 Colesville.

3.6 Passing school house on left, turn to right on private road to old Ueberroth zinc mine. Walls of old pump house with two stacks standing at edge of open pit.

3.75 Edge of open pit of Ueberroth zinc mine. Ledges of Beekmantown dolomite, almost vertical, are seen at east end of pit. Opening filled with water. Level of water fluctuates according to rainfall. Piles of waste rock in which there is little mineralization at west end of cut show brecciation and fine lamination of dolomite; southwest of pit small piles of rock containing considerable quantities of pyrite and sphalerite. Old Hartman zinc mine is located a short distance southwest of Ueberroth mine.

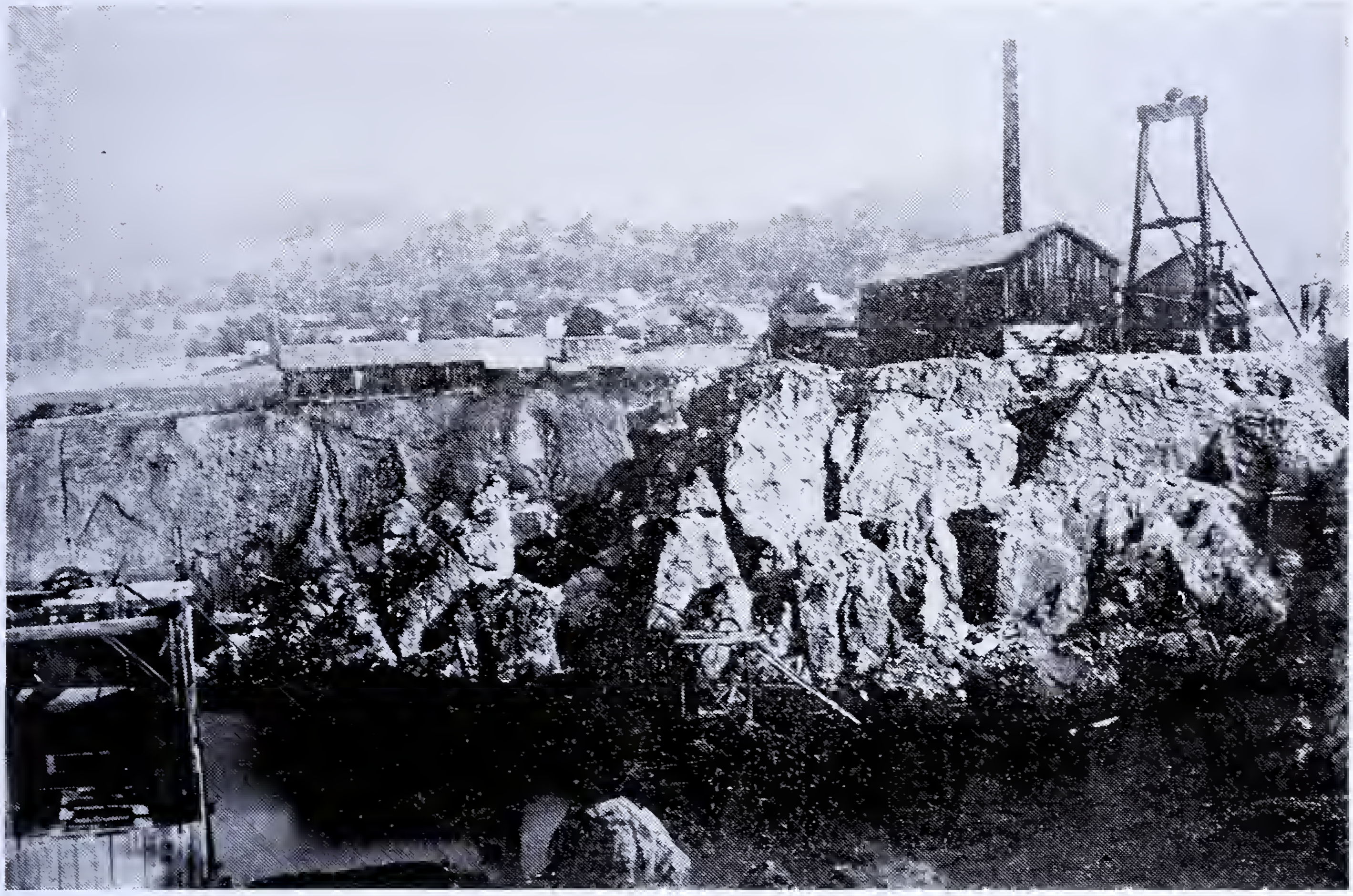

Figure 10. View of Ueberroth zinc mine, Friedensville, when in operation.

Figure 11. Present view of Ueberroth zinc mine, Friedensville. The water-filled mine is a favorite swimming pool in the summer. The water level fluctuates according to the rainfall of the region.

The Friedensville zinc mines were worked actively, with few interruptions, from 1853 to 1886. Recently a great deal of diamond drill prospecting has been done. The ore in the upper levels was mainly calamine, although some smithsonite was present. In depth the oxidized ores decreased until practically all the ore was sphalerite associated with much pyrite. The ores fill fracture openings and replace the dolomitic limestones. Much of the sphalerite was in the form of dense bluish-black structureless masses which broke with a

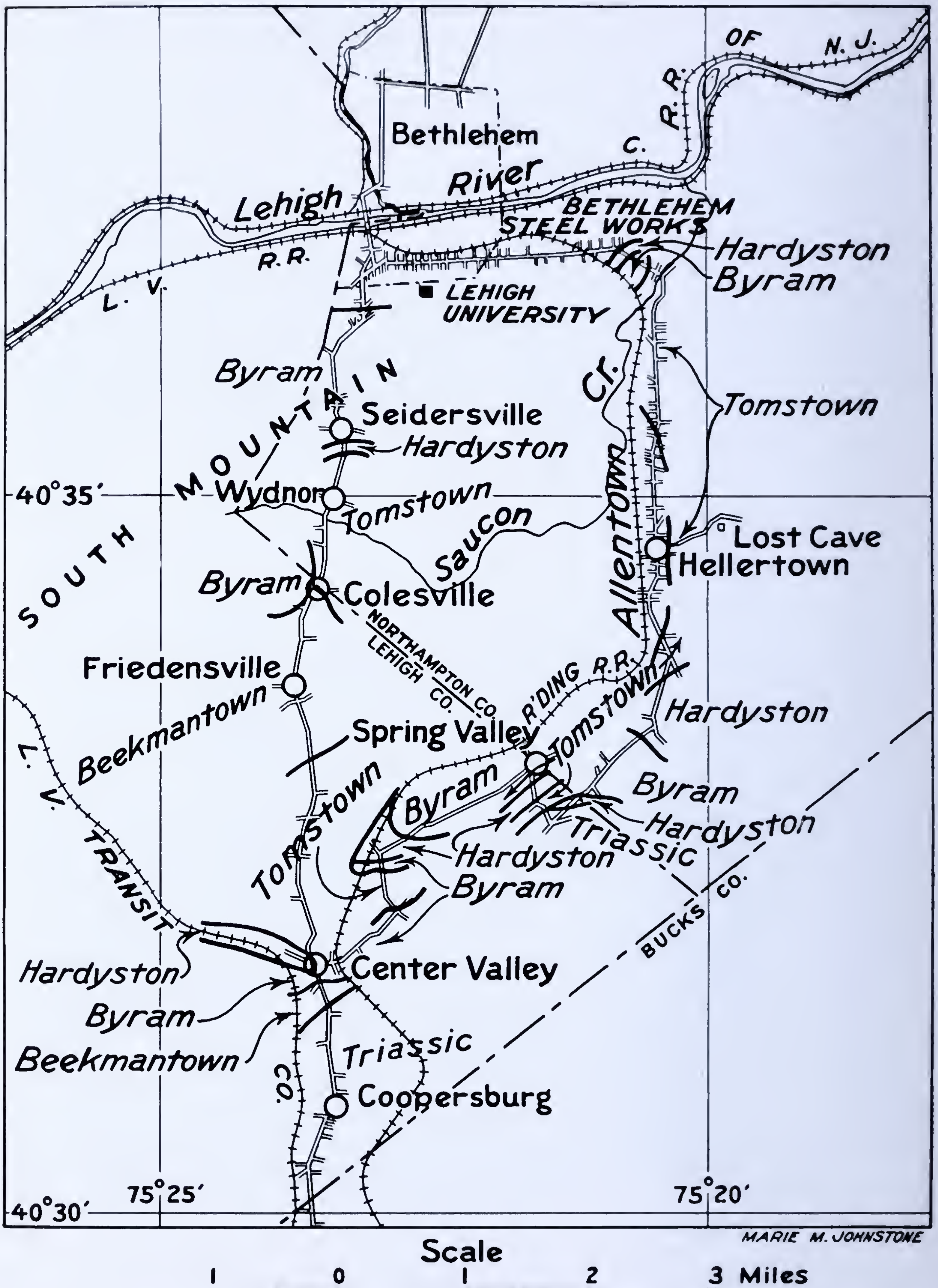

Figure 12. Map showing routes of Itineraries 1 and 2.

conchoidal fracture. Both zinc oxide and spelter were made from the ores. The fractured rock permitted much ground water to enter the mines and increased the cost of the mining operations. At present most of the known zinc ore properties are owned by the New Jersey Zinc Co.

Leaving pit, return to highway (3.85 mi.) and continue south.

4.2 Friedensville church. Correll and New Hartman old zinc mines short distance to west, Three-Cornered Lot old zinc mine short distance to east. Turn left at crossroads to new concrete highway (4.4 mi.). Continue southward on Route 12.

4.6 Deep cut on highway; excellent exposure of the dolomitic phase of the Beekmantown. Massive beds and some shaly strata. No fossils observed in rocks of cut, but characteristic Beekmantown fossil (*Lecanospira* sp.) one time found on crest of hill a short distance west of cut.

5.4 Highway cut exposing much weathered Tomstown shaly dolomitic limestone.

5.7 Old limonite iron mine in limestone short distance east of road at sign "Nirvana."

6.6 Center Valley—junction of highways 12 and 309. Walk southwest to tracks of the Interborough Electric Line and follow west for one-quarter mile, noting masses of taffy-yellow ferruginous jasper of Hardyston formation, much of it decidedly cavernous with cavities lined with drusy quartz crystals. The origin of the Hardyston jasper has been much discussed. Turn left on Route 309.

6.8 Cross hill of Byram gneiss. Normal fault on south side with fine springs a short distance west of highway. These springs appear along the fault plane. The south side has dropped down, bringing the limestone in contact with the Byram gneiss.

6.9 Intersection of concrete and macadam highway. A short distance to the southwest is a quarry in Beekmantown limestone that has been worked for crushed stone.

7.1 Contact of Brunswick (Triassic) red shale and conglomerate and Beekmantown limestone. Several poor exposures along stream.

Coopersburg. On east side of Reading R. R. south of the railroad station is located the dressing plant of Coopersburg Granite Co. The stone used is diabase quarried from a prominent hill 2 miles to the east. The stone is sawed into blocks at the quarry and hauled to the mill. Nearly all the stone is used for monumental purposes. It takes a high polish and is very attractive.

Walking south on railroad track about one-third mile, there is an excellent exposure of Brunswick sandstone and shale with thin interbedded limestone in north end of railroad cut. Block jointing is unusually well developed. Midway of cut there is the contact of diabase and Triassic shaly sandstone. The diabase is much decomposed, especially near contact.

Although not included in this itinerary, it is recommended that a visit be made to Haycock Mountain, which lies about 10 miles to the southeast of Coopersburg. On the lower north side of the mountain is a mass of diabase blocks that has received the name of Rocky Valley.

The mountain is composed of diabase. From the south side one can drive rather close to the base of the mountain. A foot trail leads to the summit. The trip is an enjoyable one, as the huge blocks of

diabase form wild and picturesque scenery. It is hoped that the mountain will be set aside as a National or State Park and the transportation routes improved in order to make it more readily accessible.

Itinerary 2. Bethlehem to Center Valley via Hellertown and Spring Valley

Miles

0.00 Center of Hill-to-Hill bridge over Lehigh River.

Drive south on Route 12, pass Church of the Nativity to signal light. Turn left on Route 412 at Hotel Wyandotte. Follow Fourth St. to east end of city.

2.75 Junction of road running west along south side of mountain. Poor exposure of Hardyston at base of hill opposite Chat-A-While Inn.

Looking westward, the end of South Mountain is plainly seen. A normal strike fault at lower slope has caused the non-appearance in outcrop of the Hardyston sandstone and brings the Tomstown or Allentown dolomitic limestone in contact with the pre-Cambrian Byram gneiss which mainly constitutes South Mountain.

One-fourth mile to the west a wide cut in glacial deposits and hill-side talus along the Reading Railroad shows a fine exposure of Illinoian glacial till. Boulders of Silurian and Devonian sandstone and conglomerates can be identified, some of which retain glacial striae. Decomposed limestone blocks are present. The exposure is reached by climbing the slope to the railroad level.

3.5 The Hellertown highway cuts through a small Byram gneiss ridge rising only slightly above the surrounding region. The exposure is poor along road. Going downhill (westward) to the roundhouse of the Reading Railroad, one sees interesting exposures of Byram gneiss and Tomstown limestone faulted together by imbricated thrust fault sheets. This is the best example of faulting of this type in the region. Continue to Hellertown.

5.0 Turn left at Pennsylvania Hotel, Hellertown, to Lost Cave.

5.65 Lost Cave (formerly known as the Hellertown Cave.)

This cave in dolomitic limestones has many attractive features. It contains typical cave formations. A small stream of clear water flows through it. The cave, which is open to visitors throughout the year, is described by Stone in his bulletin* on Pennsylvania Caves.

5.8 Continue east past cave, crossing small creek. A short distance beyond, turn north on woods road to quarry in Hardyston sandstone. This quarry has supplied much rock for Lehigh University buildings. Several types of sandstone are present. Many of the bedding-plane surfaces are stained with limonite and turgite. A private road continues past quarry to the northeast. It runs by an old iron mine in Hardyston sandstone. Specimens can be obtained here that show gradation from sandstone to limonite iron ore. Retrace route to Hellertown and continue south on Route 412.

6.55 Pennsylvania Hotel, Hellertown.

7.2 Just south of Hellertown extensive quarries in Allentown limestone are seen to the west on the opposite side of Saucon Creek. Excellent place to study character of Allentown formation. Several quarries here were formerly worked for fluxing stone for the Hellertown iron furnace.

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* Pennsylvania Topog. and Geol. Survey Bull. G3, 1932.

8.0 At crest of low hill a road leads east past a cemetery along the north slope of the hill. Along this road large masses of ferruginous jasperoid rock are seen in fields and along boundary fences where the material has been thrown by farmers.

8.1 Leave Route 412 and take road to west, passing Ebenezer Church on left. Continue west, ignoring turn to north of the better road and follow telegraph lines. Higher hills to the south are composed of Triassic (Brunswick) conglomerate. Many of the quartzite cobbles of this conglomerate are seen along fences bordering the highway.

9.3 Turn right (north) and go to Spring Valley.

9.8 Spring Valley Inn. Unusually large spring emerging along a fault.

Turn left (west). The road follows just above the fault that has brought the pre-Cambrian rocks in contact with Paleozoic limestones. Good exposures of Byram gneiss can be seen in a fresh roadside cut. The gneiss is much decomposed. Slickensides are numerous. Pegmatites and sheared gneiss are prominent.

10.7 Where forest comes down slope to highway an old magnetite mine was at one time opened by tunnel and shaft. The shaft is about 100 yards up the slope (north) from highway. Excellent specimens showing the occurrence of the magnetite in the gneiss can be picked up on old dump.

11.2 Close to road (north side), west slope of hill, Hardyston sandstone has been quarried in a few places.

11.3 At road junction turn left (south). A short distance from the turn Hardyston quartzitic sandstone is exposed in new roadside cut.

11.4 Roadside cut exposes Byram gneiss. No Hardyston exposed on south side of hill indicates a fault bringing Byram gneiss and Tomstown limestone in contact.

11.8 Crossroads. Turn right on improved road to Center Valley.

12.5 Center Valley railroad station.

Itinerary 3. Bethlehem to the Delaware Water Gap

Miles

0.00 Center of Hill-to-Hill bridge, Bethlehem, over Lehigh River. Proceed north and east to Main St., north past Hotel Bethlehem and Moravian College to Elizabeth Avenue, east to Linden St., north side of grounds of Liberty High School. Turn north on Nazareth road.

3.9 Macada store. The route thus far is on Allentown limestone.

4.7 Camels Hump, a mass of pre-Cambrian Byram gneiss west of highway brought into present position by upward folding and faulting. Ordovician (Beekmantown) limestone to north. Cambrian sandstone (Hardyston) and limestone (Tomstown) to south.

6.8 Hecktown. Turn left half a mile to plant of National Portland Cement Co. New plant employing wet process of manufacture. Quarry in a small area of down-faulted Jacksonburg cement rock. Unusually large quantity of ground water enters the Beekmantown limestone quarry. Outcrops along highway close to Monocacy Creek.

7.5 Newburg. Crossing broad belt of Beekmantown limestone.

10.0 Entering Nazareth, the plant of the Lone Star Cement Co. can be seen a short distance to the northwest and a short distance farther west is Plant 4 of the Penn Dixie Portland Cement Co. Turn east at

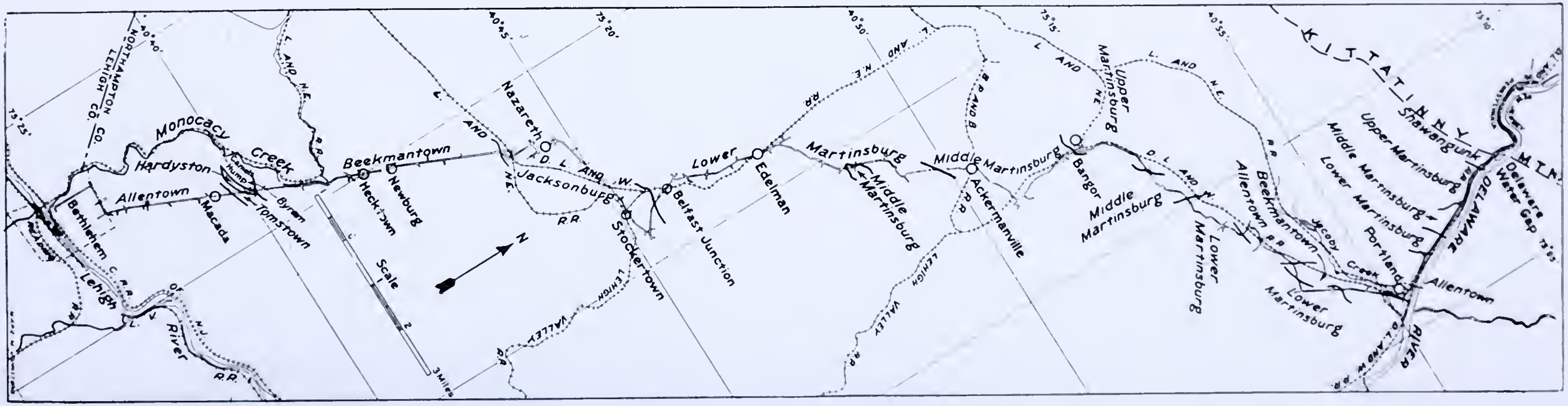

Figure 13. Map showing route of Itinerary 3.

hotel one-quarter mile to plant and quarry of the Nazareth Portland Cement Co. Interested visitors are generally admitted on application to office. Quarry is large and shows well the high-calcium stone at south side of quarry and more argillaceous beds to the north. Two thin beds of bentonite (altered volcanic ash) are exposed in south side of quarry. A form of bryozoa *(Prasopora orientalis)* is fairly common in the black argillaceous limestone in the northeast part of the quarry. Several species of brachiopods, generally fragmental, can be found in the weathered high-calcium limestone. The company uses the dry process of cement manufacture.

10.65 Nazareth. Follow Route 12 through town, turning east at northeast corner of borough.

13.00 Hercules Portland Cement Co. plant; quarry in Jacksonburg formation right of highway. Several bentonite beds in north wall of quarry. Dry process of manufacture.

13.7 Stockertown. Turn left at blinker for 1 block and then left on Route 12. Shortly the road crosses from limestone to shale formation.

14.8 Belfast Junction. Turn left on Routes 12 and 115.

16.4 Edelmans. Quarry in operation in hard vein slate, lower member of Martinsburg.

21.1 Ackermanville. From Ackermanville to Bangor the highway passes through the middle member of the Martinsburg formation in which sandy strata are abundant. The topography is hilly.

23.4 At Colonial Hotel, Bangor, turn right.

24.5 Proceed east from Bangor on Route 712. Slate quarries and huge piles of waste slate on both sides of road. Old Bangor quarry on south side of highway. Operations can be seen from highway. Slate blocks are hoisted to splitting shanties on top of hill. Considerable thickness of glacial drift overlying slate is exposed at east end of quarry.

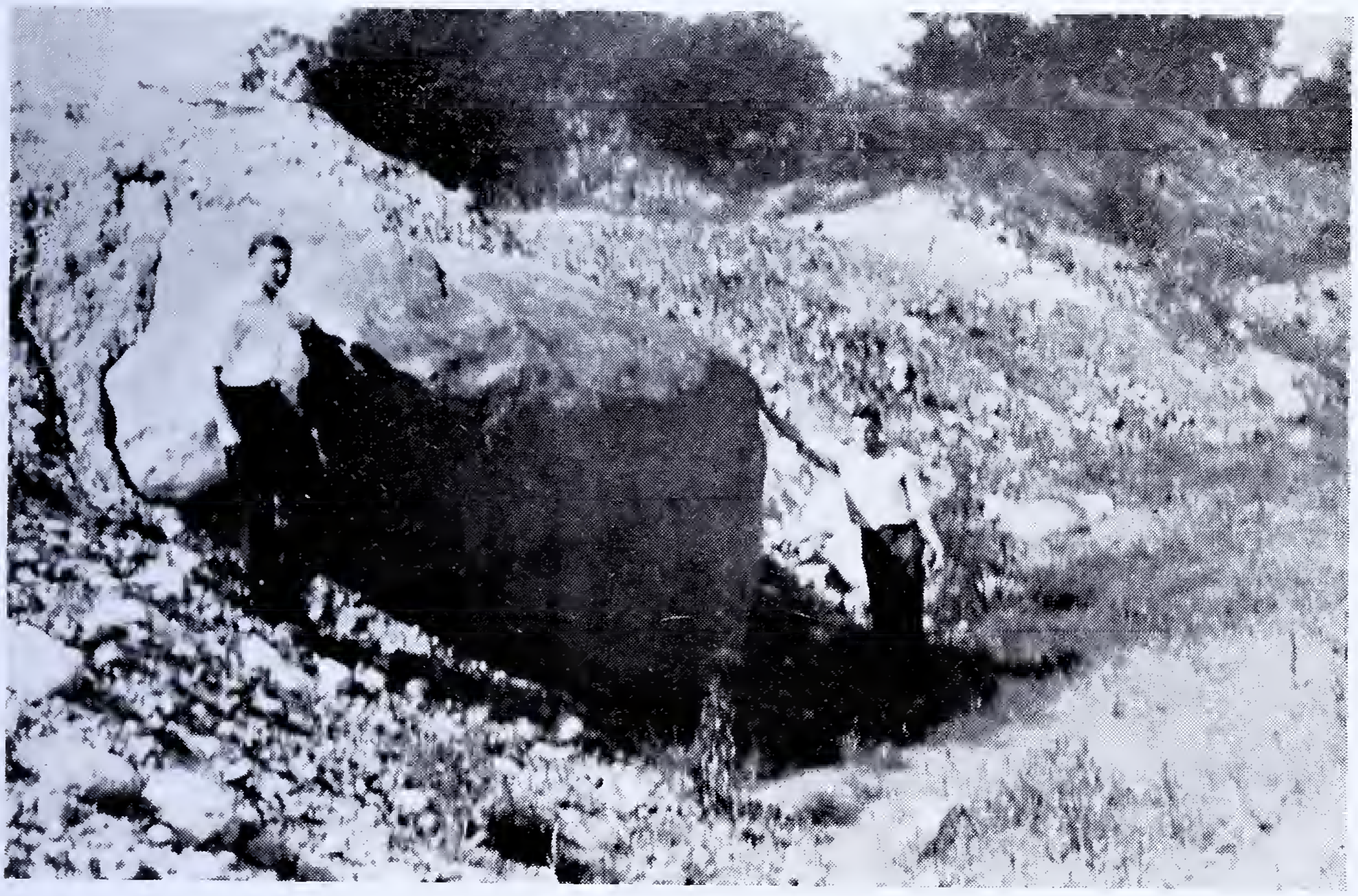

Figure 14. Huge ice-borne boulder from kame deposit, northwest of Mt. Bethel.

29.95 Kame deposit formerly worked for gravel and sand on south side of road. Opposite side of road turn left (north) to Portland Sand and Gravel Company operations approximately half a mile. Several kames are well developed in the valley of Jacoby Creek. The material is fairly well stratified with bands of fine sand and gravel, and includes large boulders and occasional huge ones.

The deposits have been actively worked for many years. The materials are crushed and sorted into various sizes for highway and building construction.

The pits contain a great variety of stones representing practically all the formations through northern New Jersey and southern New York. Some probably originated in places even more distant.

Return to the highway.

30.5 Turn left on Route 611.

32.6 Portland. Junction of river road and Route 611.

A large limestone quarry southwest of Portland in Allentown and Beekmantown formations has been extensively worked for lime, but now is filled with water.

In northwest Portland there are several small abandoned quarries in the Allentown limestone. South and southwest of the large Portland quarry are several quarries in the upper Beekmantown in which low- and high-magnesian strata are interbedded.

Still farther south, about 0.8 mile south of Portland, close to the Martinsburg slates are two small quarries in the Jacksonburg limestones. Some of the beds are extremely fossiliferous. R. L. Miller* has listed the following fossils from this region:

Pachydictya sp. cf.	*Rhynchotrema* sp.
Pachydictya acuta (Hall)	*Proetus* sp.
Rhinidictya sp.	*Dolcroides* sp.
Strophomena sp.	*Leperditia fabulites*
Dalmanella rogata	*Scenidium anthonensis*
Isotelus gigas	*Monotrypa* sp.
Sowerbyella sp.	Crinoid fragments

All of these Cambrian and Ordovician limestones constitute a block that has been up-faulted in the Martinsburg. The block in Pennsylvania extends south-southwest from the Delaware River for about 3½ miles. It is about 1 mile wide in the widest portion.

Continue north on Route 611 along the Delaware River.

34.75 Excellent section of high terrace gravels opposite bridge over railroad, and at other places. Materials rudely stratified, thickness 100± feet. These are well described by Freeman Ward in a recent publication† of this Survey.

36.2 First high cliff bordering highway entrance to Delaware Water Gap. The Delaware Water Gap is described in a report by Bradford Willard recently issued by this Survey.‡

* Geol. Soc. America Bull., vol. 48, pp. 1696-1697, New York, 1937.

† Pennsylvania Topog. and Geol. Survey Bull G 10, 1938.

‡ Pennsylvania Topog. and Geol. Survey Bull. G 11, 1938.

Figure 15. Road cut in high level terrace of the Delaware River between Portland and the Delaware Water Gap.

Itinerary 4. Bethlehem to Little Gap

Miles

0.00 Center of Hill-to-Hill bridge, Bethlehem. Proceed north and east on Route 12. End of bridge turn left on Main Street.

1.2 Follow Main Street, passing Hotel Bethlehem and Moravian College. Turn right on Elizabeth Ave., following Route 12 east.

1.6 At Bath sign turn left on North Center St.

3.75 At west end of Pine Top there is a good exposure of Byram gneiss along roadside. This gneiss ridge is part of a block of pre-Cambrian gneisses in fault contact with the Tomstown (Cambrian) limestone on south and Beekmantown (Ordovician) on north. East of the highway the ridge is prominent and extends for about 1¼ miles. East portion is named Camels Hump. On the west side of Monocacy Creek, the pre-Cambrian contains Franklin limestone, graphitic in character, and Franklin quartzite and graphitic schist. The limestone has been quarried close to the creek.

About one-third mile to the east there is a very large spring on north side of Monocacy Creek which appears to be a part of the creek that has come by an underground route past Hanoverville, leaving the surface stream, which makes a large bend to the east. The spring always has heavy flow, even when the channel of the creek past Brodhead is dry and the stream bed overgrown with weeds.

Cross Monocacy Creek and continue north on concrete road, passing over Beekmantown limestone which outcrops in fields on both sides of road. The limestone formerly was quarried in a few places for lime burning.

5.00 Optional trip—mileage not included in itinerary.

At farm of Charles Reaser just north of barn turn west on dirt road half a mile to the old Henry Goetz limonite iron ore mine,

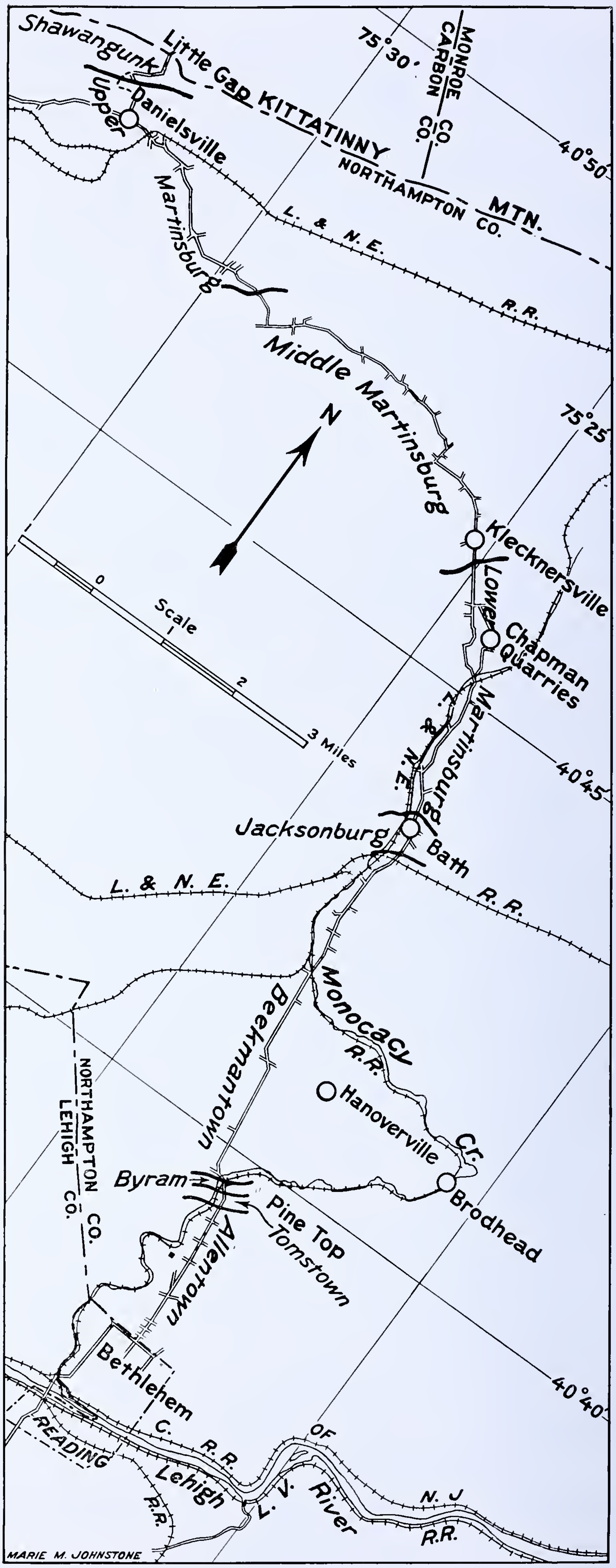

Figure 16. Map showing route of Itinerary 4.

where extensive open-pit mining was long carried on. The large dump pile of clay and other débris is visible from highway. The mine is typical of the limonite iron mines formerly worked in numerous places in the limestone region throughout the Lehigh Valley. At present time some of the ferruginous clay, washed from the ore, is being removed by one of the cement companies for the manufacture of iron-rich portland cement.

Continue north on concrete road.

7.85 Enter Jacksonburg limestone cement belt. The plant and quarry of the Keystone Portland Cement Co. can be seen on the west side of Monocacy Creek. Penn Dixie Portland Cement Co. plant 6 is about half a mile east of Bath. The sharp hill rising to the northwest of the Keystone quarry is composed of Martinsburg slate. The contact between the more resistant (less soluble) slate and the less resistant (more soluble) Jacksonburg limestone is commonly shown by such a change in topography.

8.6 First stop light in Bath. At second traffic light turn left one block and then north at traffic light on Route 987 following Monocacy Creek. Outcrops of lower member of Martinsburg formation are numerous along the roadside.

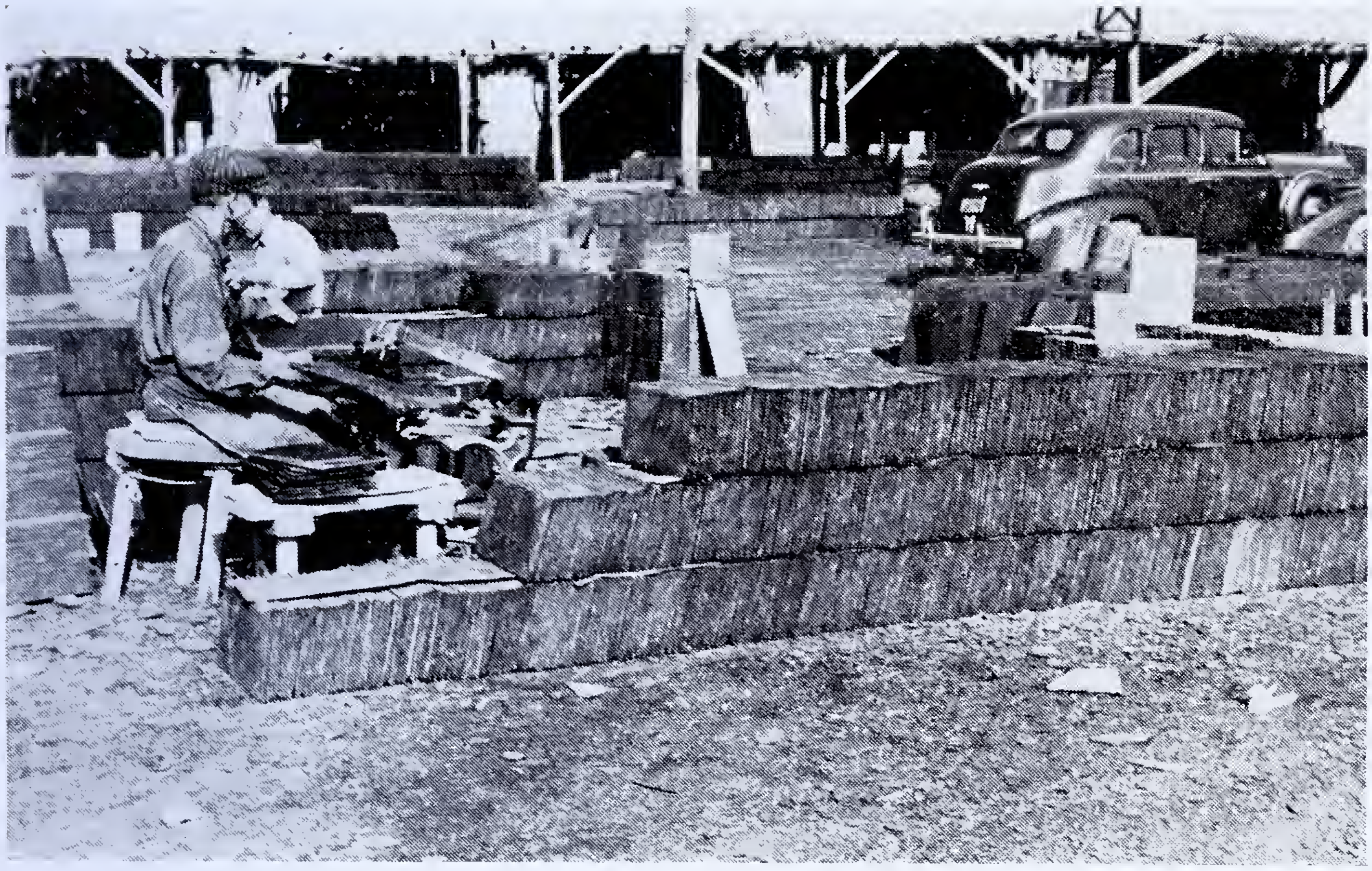

Figure 17. Punching nail holes in roofing slate. Piles of slate ready for market.

10.8 Entering Chapmans, turn right up the hill to Chapman quarry, passing residences and schoolhouse built of waste blocks of slate.

11.2 Turn right off highway into grounds of Chapman quarries. Leaving car at piles of prepared roofing slates, one can walk south a short distance for an excellent view of the large quarry which has long been worked. Folds can be readily seen in walls of quarry. Methods of quarrying can be observed and the transportation of the blocks to the finishing sheds. The processes of roofing slate manufacture can be followed. The large piles of waste slate are conspicuous and show the high percentage of unusable material taken from the quarry.

Attention should be called to the abundance of "ribbons" (beds) and their siliceous character. This quarry is opened in the "hard vein" slate belt of the lower member of the Martinsburg formation. These characteristics should be compared and contrasted with the slate quarried at a later location (18.45 miles).

Return to main concrete highway at foot of hill and turn right, continuing to the northwest on Route 946.

13.1 Klecknersville crossroads. A short distance before entering Klecknersville the middle member of the Martinsburg formation, which contains considerable sandstone, is encountered. There is little change in topography at this point. In other places the middle

Figure 18. Block of "ribbon" slate, Chapman Quarries. The "ribbons" are the beds. The upper smooth surface is the cleavage plane.

member, being more resistant to stream erosion, rises prominently above the erosion surfaces of the lower and upper members. The stream divides show the Harrisburg peneplane well developed. It averages somewhat above 800 feet elevation.

Follow northwest toward Danielsville on Route 946.

18.45 Turn left off main highway on dirt road leading to quarry of National Slate Co. The quarry is 175 feet deep. It shows typical characteristics of the "soft vein" slate in which the "ribbons" are few and almost all very black. In contrast with the "ribbons" of the "hard vein," these decompose and disintegrate readily so that practically all slate with ribbons is discarded. Frequently one notes much pyrite in these black "ribbons."

Return to highway and continue northwest on concrete highway.

19.7 Railroad station, Danielsville. Continue to crossroads (hotel, store, etc.) at 20.0 miles.

20.0 Turn right on dirt road toward Kittatinny (Blue) Mountain.

20.2 Follow road to left for ascent of mountain.

20.85 First outcrop of Shawangunk conglomerate and sandstone dipping south downhill. This south dip is unusual, as all the Shawangunk strata exposed in the Lehigh Gap and Delaware Water Gap are dipping north in the normal manner. At this point the mountain-building compressive forces have overturned the strata.

21.1 Near top of mountain at outcrop marked by surveyors as 60 there are some good specimens of *Arthophycus harlani*, a typical fossil of the Shawangunk.

21.5 Near crest of ridge, to right of road, there is an area covered with angular to partly rounded large blocks of Shawangunk sandstone and conglomerate. The area is devoid of soil and vegetation other than the lichens on the rocks. This place is locally known as "The Devil's Potato Patch." There is no exposure of rock in place in the center of Little Gap, but shortly after the road begins the descent on the north side of the mountain an exposure of red to gray shale and sandstone of the Clinton formation is seen in a shallow road cut.

From the top of Kittatinny (Blue) Mountain fine views are to be had. Southward the Great Valley can be distinctly seen on a clear day with South Mountain in the background. To the north several ridges and valleys parallel to the mountain are in sight, with the Pocono Plateau in the distance.

At the time of writing (February, 1939), plans are well under way for a tunnel through the base of the mountain a short distance east of Little Gap, to bring water from Wild Creek to the city of Bethlehem. In the prospecting work for this tunnel by diamond drilling, at one place a short distance south of the base of the mountain, talus and probably some river alluvium was penetrated to the depth of 130 feet without reaching the underlying Martinsburg slate.

Itinerary 5. Easton to Upper Black Eddy and Ringing Rocks

Miles

0.00 Easton—South side of Easton Square. Go south on Route 611 on South Third Street. Cross Lehigh River and turn left. Follow river road.

0.75 Roberts quarry (idle for several years). It was first worked for lime burning, but later for crushed stone. The dolomitic limestone belongs to the Allentown formation. The beds are fairly massive with a few thin layers. The south wall shows alternate light and dark beds, which is a characteristic feature of the Allentown formation. Numerous small and large faults can be seen. Certain layers exhibit numerous gash veins of quartz; others show fine examples of intraformational conglomerate or edgewise conglomerate.

1.35 Abandoned quarry of Allentown limestone. Alternating light and dark beds well shown. Fossils of *Cryptozoon proliferum* are present, though not numerous nor well preserved. There is much intraformational conglomerate. Some thin shale layers.

1.90 Hardyston conglomerate and sandstone exposed at base of hill along old trolley line west and slightly uphill from highway. This place is of particular interest because it is the only known example in this region of Hardyston intruded by a pegmatite dike. It furnishes evidence of a post-Cambrian pegmatitic invasion. The Hardyston is in contact with Byram gneiss.

2.6 Two well-defined terraces of Delaware River; road follows upper terrace. Gravel at one time was extensively worked on river side of road and shipped by canal to the Philadelphia district.

3.5 Section of Moravian Heights formation well exhibited at several points along highway for half a mile.

5.0 Excellent exposure of Tomstown dolomitic limestone west side of highway in old quarry and along abandoned trolley line. It is typical of the formation in that it exhibits extremely massive dolomitic limestone interbedded with considerable shaly material.

5.35 Small hill of Tomstown shale and shaly dolomite between highway and canal. This is an unusually thick zone of shale in the Tomstown formation. On the map of the Second Geol. Survey this area was marked "Hudson River" (Martinsburg) shale.

5.75 Center of Raubsville.

6.4 Just below bridge over canal to the Pennsylvania Power & Light Co. Raubsville hydro electric station. An abandoned quarry in the Allentown limestone on west side of highway shows unusually fine large ripple marks on bed forming north wall of quarry. Strata almost vertical.

Figure 19. Large ripple marks in surface of steeply dipping Allentown limestone in abandoned limestone quarry along Delaware River highway near Raubsville.

7.4 Northeast corner of Bougher Hill, a quarry just west of highway shows highly arkosic Hardyston and Byram gneiss. Both types of stone have been quarried. The conglomeratic phase of the Hardyston is well shown. The beds are practically vertical with a strike parallel to the trend of the hill. Some beds of fine-grained quartzite present.

8.2 Bucks-Northampton county line marker (location not in agreement with Easton topographic map). Byram gneiss is exposed for a considerable distance on west side of highway.

9.9 Riegelsville. Two well-developed gravel terraces. An active gravel and sand pit near the highway at the south end of the village (entrance just beyond curve) has a working face 25 feet high in the upper terrace. The sand and gravel are well sorted in layers. Lenses of cross-bedded sand occur and a few huge masses of water-worn conglomerate and angular gneiss up to 10 feet in diameter which probably were floated down the river from the front of the glacial ice sheet in the Delaware Water Gap region enclosed in large blocks of ice.

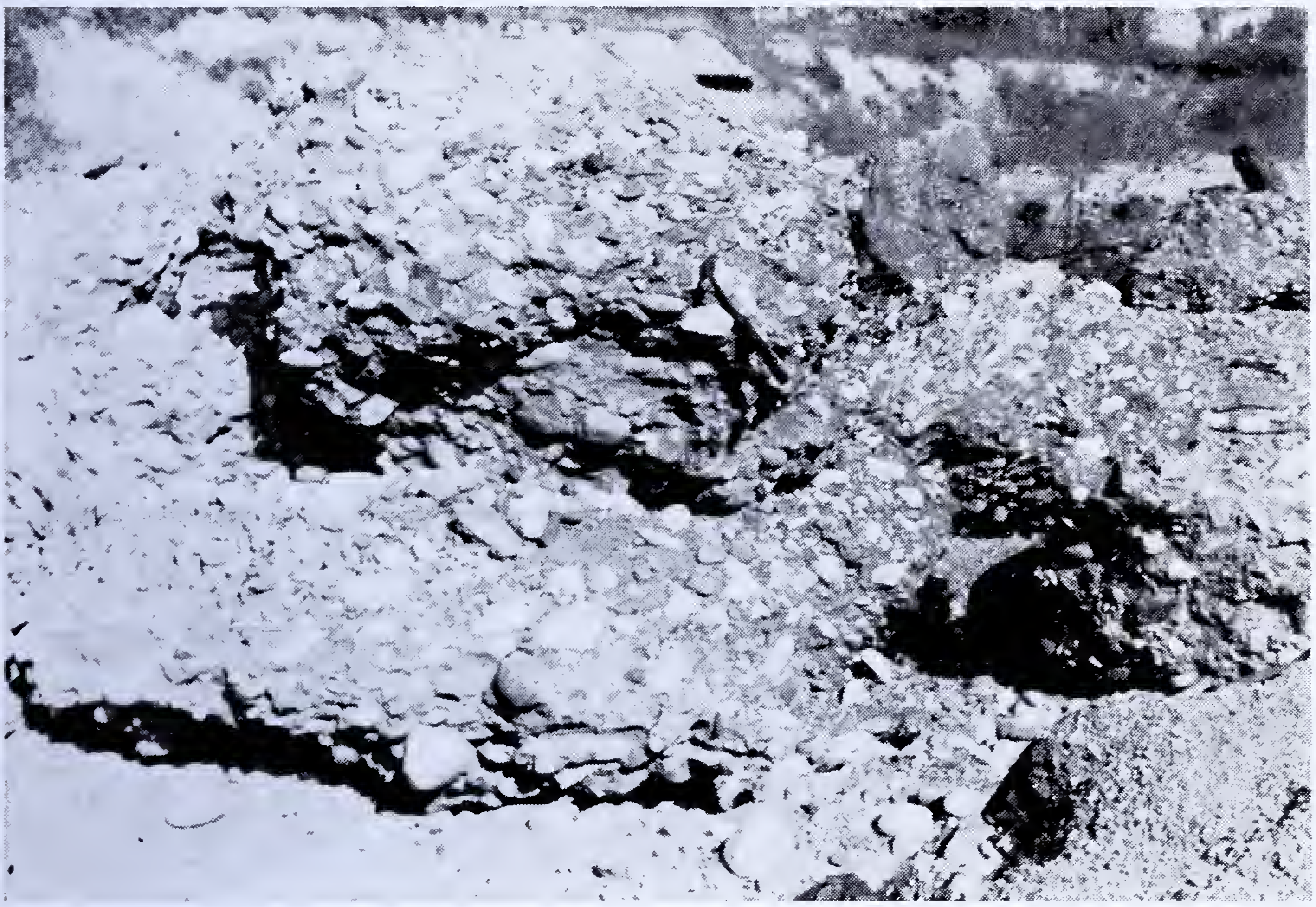

Figure 20. Cemented masses of Delaware River terrace gravels, Riegelsville.

10.35 Durham Furnace, mouth of Durham Creek. The limestone hill on north bank of Durham Creek close to the highway contains part of a cave in which Pleistocene or Recent vertebrate fossils were found nearly 100 years ago. Along Durham Creek (right bank) a short distance upstream magnetite iron ore mines were long worked. Mining started in 1727. The ore occurs in Pochuck gneiss in Rattlesnake Hill and Mine Hill.

Indian jasper pits in the Hardyston formation are located near the crest of Rattlesnake Hill on the south slope.

Continuing south good exposures of Pochuck gneiss are seen along highway.

11.0 Monroe. Here is the contact of the Tomstown (Cambrian) limestone and Brunswick (Triassic) shale. A strong spring emerges at the contact. The exact contact is not visible, but must be a fault as shown by the northward dipping strata of the Triassic which otherwise would pass beneath the Tomstown limestone.

Just south of the contact is an exposure of Brunswick red shale and sandstone with some layers of coarse conglomerate containing pebbles and angular fragments of quartz, quartzite and limestone.

There are several excellent exposures of Brunswick red shale and sandstone between Monroe and Gallows Run.

12.3 Cross Gallows Run, turn left on Route 32.

13.3 One mile below, enter the Narrows. High bluffs of red shale and sandstone extend for some distance.

14.3 One may reach the Ringing Rocks by taking right-hand road up steep hill, turn left at top of hill and proceed eastward about one mile. Park car and take path through the woods to the Ringing Rocks. For better road, continue on river road to north end of village of Upper Black Eddy.

16.5 Gravel and sand deposits of alluvial origin are being worked on the river terrace back of Nockamixon Inn a short distance up from the Delaware River bridge. A fine view can be had of the high bluffs of Triassic red shale and sandstone on New Jersey side of river.

16.65 North edge of Upper Black Eddy a short distance above Delaware River bridge. Turn right on improved macadam road, crossing river terrace and ascending hill.

18.15 Leave macadam road, take improved red dirt road to right across bridge for 0.35 mile.

18.5 Park car and take trail to right through woods to Ringing Rocks.

The ringing rocks consist of a sheet of diabase of Triassic age that has been exposed by the wearing away of the once overlying Brunswick shales and conglomerates. By frost work and chemical weathering, the dense igneous rocks have been broken into blocks. These have become more or less rounded by exfoliation. Any small particles have been carried away by erosion so that a field of boulders with no soil and no vegetation has been left. These rocks have been attributed to glaciers by some observers. This definitely does not explain their origin. Any mass of glacial boulders in this region would be composed of different kinds of rock picked up in many places as the ice moved south. Further, the ice sheet did not extend down the Delaware River valley to this point.

Individual boulders struck with a hammer emit a metallic ringing sound. Different notes are produced by the rocks so that it is possible to play simple tunes by stationing a group of people over the field where the rocks give the proper tones and directing them in turn to strike particular stones.

Why some rocks will ring and others will not has not been well understood. The density of the rocks, the lath-like character of the feldspars of the diabase, the shape of the rocks and the manner in which they are supported seem to explain the phenomenon. At a glance one can seldom pick out the desirable ones, as a huge rounded rock may give a clear bell-like tone and a slab of similar stone may produce only a dull sound.

Only a short distance east of the boulder field, in the bed of a small stream, just above a waterfall, the underlying Triassic shales crop out. They were thoroughly baked by the heat of the lava so that they are extremely hard.

The Bucks County Historical Society owns the Ringing Rocks and adjoining acres. Plans have been formed for the construction of a good road leading directly from the river road, thus making them more accessible.

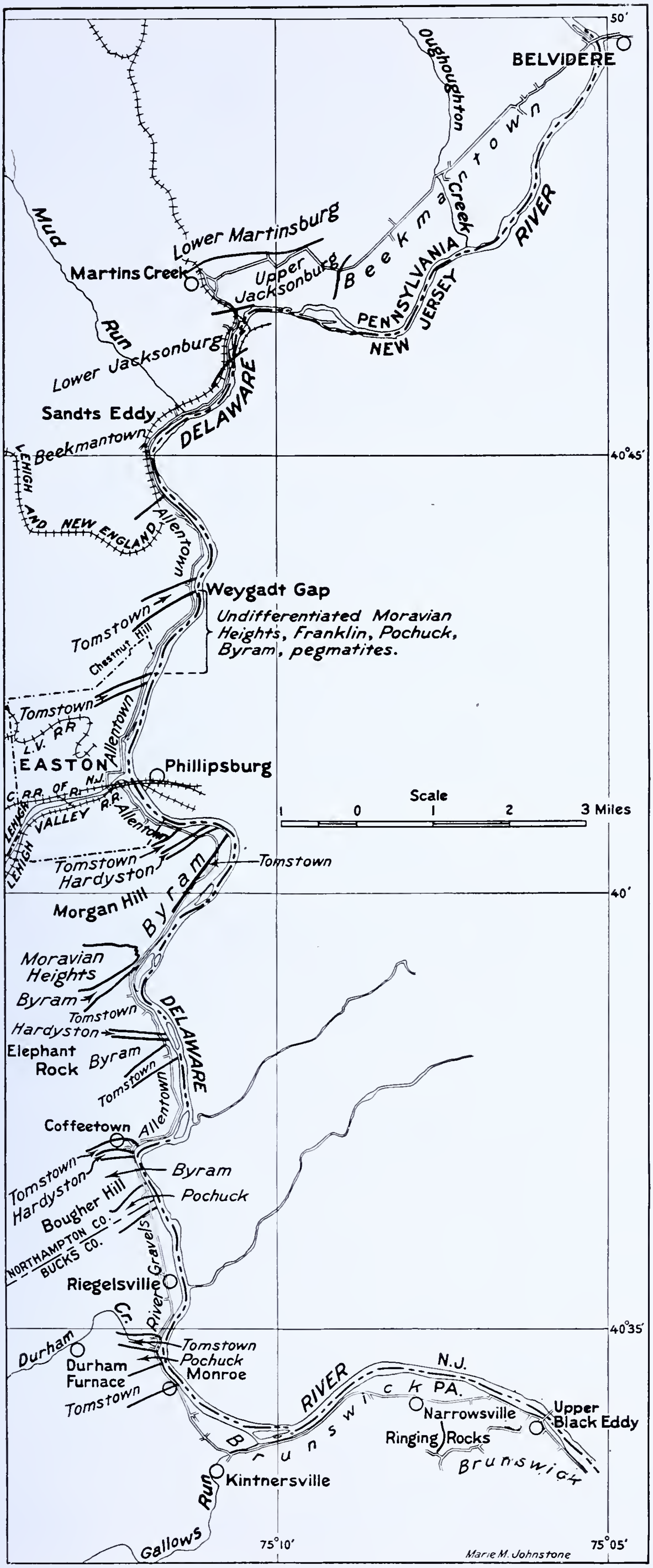

Figure 21. Map showing routes of Itineraries 5 and 6.

Itinerary 6. Easton to Delaware River at Belvidere, N. J.

Miles

0.00 Easton, east side of square. East on Route 22 (Northampton St.) to Front St. Turn left at signal light on Front St. and go north. Turn right at North Delaware Drive, Route 611.

0.9 Pass along cliffs of Allentown dolomitic limestone. Excellent exposure opposite Easton municipal bathing beach. Examples of gash veins, black flint segregations, oolites and sun cracks can be seen.

1.7 Pass plant of Lehigh Water Co.

1.8 Williams serpentine quarry.

This is the most important mineral-collecting quarry in Pennsylvania. Impure dolomitic limestones of the Franklin formation have been intruded by pegmatites. Much of the original dolomite has been converted into serpentine and talc, which are quarried and pulverized for use as a mineral filler.

The most interesting and unusual minerals found in this quarry and nearby quarries are those of the uranium and thorium series, some of which are not positively known elsewhere in the United States.

The following list of reported minerals from this locality is believed to be fairly complete at the present time. It does not contain all the sub-species or varieties.

Minerals occurring in Williams serpentine quarry:

actinolite
anthophyllite
apatite
aragonite
asbestos
augite
autunite
azurite
barite
biotite
brucite
calcite
carnotite
celestite
chalcocite
chalcopyrite
chloritic vermiculite
chrysocolla
coccolite
cuprite
diopside
dolomite
feldspar
fluorite
galena
graphite
gypsum
hematite
hydromagnesite
ilmenite
limonite
magnesite
malachite
marcasite
molybdenite
muscovite
nephrite
phlogopite
phosgenite
pyrite
pyrolusite
quartz
serpentine (many varieties)
sphalerite
strontianite
talc
titanite
thorianite
thorium gummite
topaz
tourmaline
tremolite
uralite
uranophane
vesuvianite
wernerite
wulfenite
zaratite
zircon

2.4 Many well-developed potholes in granite pegmatite in river.

2.8 Weygadt Gap. High cliff of gneiss containing much black tourmaline. Numerous faults made it necessary to remove much rock for safety of highway traffic. Slickensides are prominent.

4.45 Contact of Allentown and Beekmantown limestones. Actual contact not exposed. Beekmantown contains interbedded low- and high-magnesia rock. Continuing north one passes by cliffs of Beekmantown limestone, mainly highly magnesian.

5.75 Cross Mud Run. Sandts Eddy plant of the Lehigh Portland Cement Co. Quarry on east side of run one-quarter mile north. Fossils are fairly abundant in the Jacksonburg cement rock in certain parts of the quarry.

7.55 Martins Creek plant of the Alpha Portland Cement Co. Large quarry in Jacksonburg limestone east of plant. Beekmantown dolomitic limestones are exposed in south wall of quarry overlain by lower member of Jacksonburg. High cliff on north face of quarry composed entirely of upper member of Jacksonburg. The lower member (cement limestone) contains much more $CaCO_3$ than the upper member (cement rock).

8.10 Turn right and continue on Route 611 across Martins Creek. On the west side of the creek a pit in coarse terrace gravels has been worked. It is visible from the bridge.

Ascend hill through deep cut in Jacksonburg cement rock.

9.2 Top of Three Church Hill by church leave Route 611, continue down hill on Route 275, Belvidere road.

10.0 Where road bends at stream an abandoned lane leads down steep hill. R. L. Miller* reports finding here a few ledges of Jacksonburg limestone from which he collected the following fossils:

Pachydictya acuta Hall
Rhinidictya sp. cf. *R. mutabilis* Ulrich
Lingula elongata Hall
Lingula sp.
Sowerbyella sp.
Parastrophina hemiplicata (Hall)
Rafinesquina alternata (Conrad)
Strophemena sp.
Dalmanella rogata (Sardeson)
Pelecypod indet.
Isotelus fragment

12.1 Cross Oughoughton Creek. An abandoned sand and gravel pit is located a short distance to south of road on east side of stream. The Pleistocene terrace gravels overlying Beekmantown limestone are well exposed.

Continue east over unusually flat terrace underlain by thick deposit of coarse to fine alluvial materials.

13.3 Front of Wisconsin terminal moraine. Irregular hillocks are numerous and masses of glacial boulders taken from the fields are piled along the boundary fences. The morainal topography presents a striking contrast to the flat alluvial terrace. The morainal topography continues almost to the Delaware River. A few roadside cuts reveal constitution of the moraines.

15.0 Entrance to bridge over river to Belvidere, N. J.

Itinerary 7. Allentown to Center Valley

Miles

0.00 Monument at 7th and Hamilton Streets, Allentown. South on 7th Street. Follow Route 309, turning east on Union Street, then south on Lehigh Street, crossing Little Lehigh Creek, passing under railroad and turning left on Auburn Street, then south on 5th Street.

1.55 Clay pit west side of highway worked by brick plant is in residual and glacial clay with numerous large glacial boulders. Large area has been excavated to depth of 10 to 15 feet. Portions are comparatively free from rock, but other parts contain great quantities of rock fragments of all sizes up to 5 feet in diameter. The material is unsorted Illinoian till with some residual limestone clay. Hardyston sandstone and conglomerate in angular fragments up to several feet in diameter are the most abundant rocks. The Hardyston cobbles and boulders are mainly recognized by their arkosic character. Some show fine banding.

* Geol. Soc. America Bull., vol. 48, p. 1705, 1937.

Figure 22. Pit of Illinoian glacial till worked for brick clay. Between Allentown and Mountainville.

Shawangunk conglomerate and quartzite brought from Kittatinny (Blue) Mountain are also abundant, mainly fairly well rounded. Of minor importance are blocks of Pochuck and Byram gneisses and red to gray Silurian and Devonian sandstones. The underlying rock is Allentown limestone, which in places is thoroughly decomposed to a clay containing sericitic fragments. Some weathered loose blocks of the dolomitic limestone occur in the glacial clay.

The greater age of the Illinoian in comparison with the Wisconsin till of the Delaware Water Gap region is shown by the rotten character of the gneiss boulders.

2.6 Normandy Street. Opposite this street on the hill slope east of the highway is the contact of pebbly Hardyston and Byram gneiss. The exposure is fairly good. An old limonite iron ore mine in the Hardyston formation is 150 yards west of the highway. Many loose Hardyston blocks show the transition between fine-grained brownish-yellow sandstone and limonitic iron ore.

This same iron ore horizon with numerous old iron mine workings and exposures of ferruginous chert and sandstone continues close to the same level on South Mountain to Emmaus. The mines were worked by open cut and shafts. Considerable pyrite was found at depth in some of the mines.

3.2 Summit of mountain. Turn left on narrow road for 0.3 mile. Large masses of finely-banded Pochuck gneiss can be seen in woods south of road on crest of mountain. Drive east toward Big Rock, passing other huge masses of Pochuck gneiss.

3.8 Park car at sign "Big Rock" and follow path one-quarter mile south to Big Rock. Huge masses of finely-banded Pochuck gneiss with few joint planes stand high above the general surface of the mountain crest. From top of rock a fine view can be had of Allentown and vicinity to the north and Saucon Valley to the south. Much epidote

Figure 23. Masses of Pochuck gneiss, in place, rising above general level surface. Crest of Lehigh Mountain east of Summit Lawn.

has developed along joint planes, in places as much as one-quarter inch thick.

Big Rock has long been a favored place for picnics.

Return to highway Route 309 (4.3 miles). Continue south on concrete highway.

5.3 Intersection of road to Colesville. Short distance east along Colesville road, Jacksonburg fossiliferous limestone is exposed in cuts. This area of Jacksonburg is part of a down-faulted block with a vertical displacement of approximately 4,000 feet. It brings Jacksonburg in contact with pre-Cambrian gneiss.

Continue south on highway.

6.05 Crossroads. Sunnyside suburbs. Turn left, following highway to turn in road; park car. East of here is a very extensive old limonite iron ore mine (Greene mine) in limestone. The excavation is now filled with water. The dumps of waste material show much pyrite and occasional masses of ferruginous taffy-yellow rock composed entirely of quartz crystals, many of which show fairly perfect crystal faces. Some crystals are doubly terminated. This rock is believed to be a replacement of dolomitic limestone.

Return to concrete highway and go south.

8.00 West edge of Center Valley. Park car and go south to cut of Lehigh Valley Transit line. Excellent exposures of jasperoid Hardyston containing many cavities lined with drusy quartz crystals.

Itinerary 8. Allentown to Treichlers via Fullerton, Catasauqua and Cementon

Miles

0.00 West end of Tilghman Street Bridge over Lehigh River. Go north on Front Street.

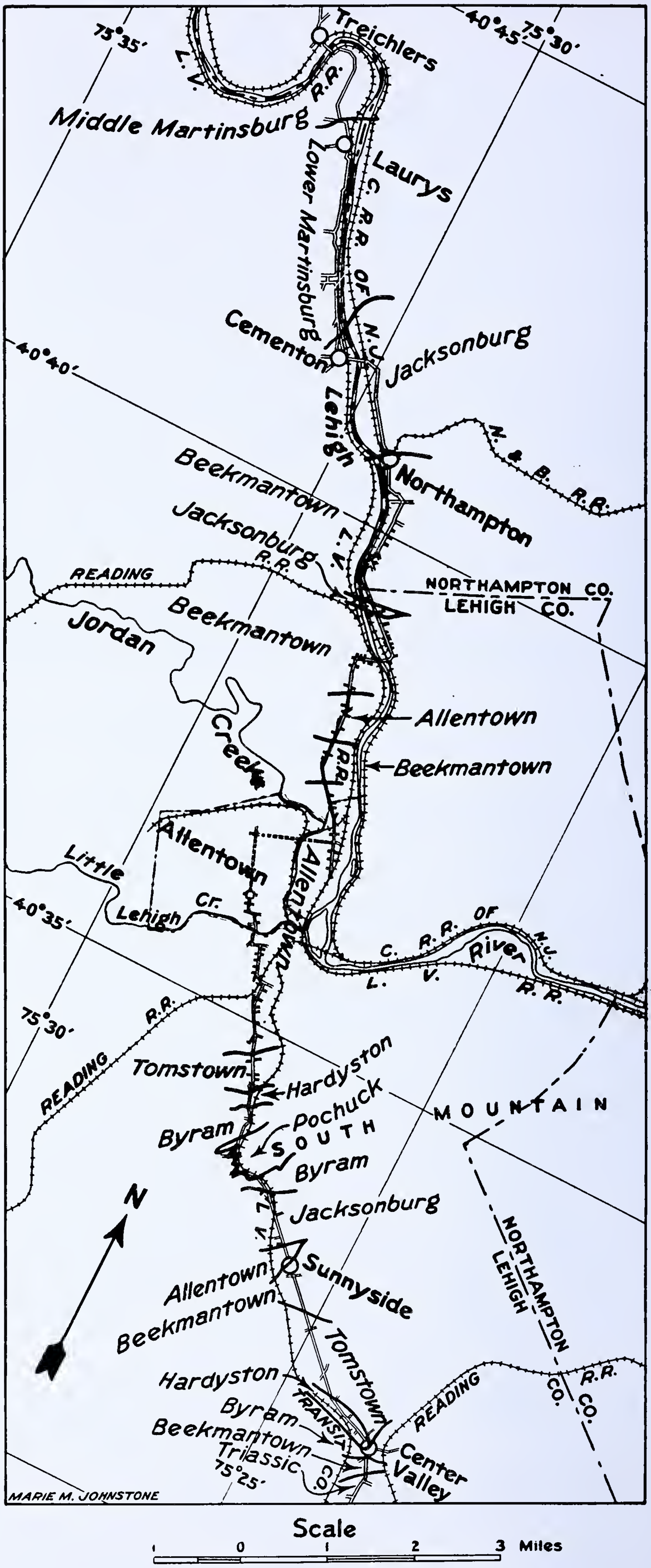

Figure 24. Map showing routes of Itineraries 7 and 8.

0.2 Two railroads, Lehigh Valley and Central R. R. of N. J., pass under highway in deep cut. Allentown limestone with abundant *Cryptozoa* exposed in both cuts. The south cut shows better example of the large heads of *Cryptozoa*. The north cut shows well the alternate light and dark beds of dolomitic limestone, typical of the Allentown formation. Some sandy layers show cross bedding. Edgewise conglomerate is abundant here.

Continue north to Fullerton. Cross Lehigh River to Catasauqua and follow car line through town. Continue north on Northampton road.

4.9 Park car at railroad crossing in small valley just before entering Northampton. Follow tracks to east about 250 yards where old limestone quarry once worked for furnace flux exhibits the most complicated folding of limestone in the entire district. The limestone is of Beekmantown age. A few poor specimens of coiled gastropods and of *Orthoceras* occur in the massive limestone.

5.2 Turn right on private road to office of the Universal Atlas Portland Cement Co. This is the largest cement plant in the Lehigh Valley. The quarries in the Jacksonburg cement rock are some distance north of the office. Lenses of gray crystalline high-calcium limestone occur in the black argillaceous limestones. Where these are weathered at the surface they seem to be composed largely of crinoid plates and fragmental brachiopods and corals.

Continue on Main Street, Northampton to bank in north part of town.

6.5 Turn left (west).

6.7 Just before reaching the bridge across the Lehigh River, a road leads north to the plant of the Lawrence Portland Cement Co. The quarry lies some distance east of the mill. It is the deepest cement quarry in the valley.

7.0 Cementon. The plant and quarry of the Whitehall Portland Cement Co. is seen to the left. The quarry shows typical Jacksonburg cement rock. Turn right (north) following main road.

9.55 Laurys.

10.45 High terrace Lehigh River alluvial gravels are well exposed in roadside cut.

10.7 Treichlers Bridge on Route 145. Along roadside south of bridge there is an exposure of "hard vein" slate considerably weathered. It is a part of the lower member of the Martinsburg formation.